AN ESSAY ON THE HISTORY OF ELECTROTHERAPY AND DIAGNOSIS

HECTOR A. COLWELL

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THE HISTORY OF ELECTROTHERAPY

WILLIAM GILBERT, M.D. (1540-1603.)
President of the Royal College of Physicians.

AN ESSAY ON THE HISTORY OF ELECTROTHERAPY AND DIAGNOSIS

BY

HECTOR A. COLWELL,
M.B., L.R.C.P., M.R.C.S., D.P.H.,

Assistant Radiologist, King's College Hospital; Joint author of "Radium, X-Rays, and the Living Cell"; "Practical Biological Chemistry" (trans.); formerly Pathologist to the Thirty-Sixth General Hospital; Capt. R.A.M.C., attached Royal Serbian Army; Senior Assistant to the Director of the Cancer Research Laboratories, the Middlesex Hospital; Scholar of St. Bartholomew's Hospital, etc., etc.

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DEDICATED TO

ROBERT KNOX, M.D.

PREFACE.

This little book hardly needs a preface, except to express my gratitude to the many kind friends who have helped me. I have more especially to thank Mr. C. J. Thompson, of the Historical Medical Museum, for the pictures of John Hunter, Musschenbroek, Beccaria and Galvani, and for the caricature of the Metallic Tractors; Dr. van der Plaats, of Utrecht, for the picture of the bust of Musschenbroek, which I believe has never before been published; Mr. Hewitt, the Librarian of the League of Red Cross Societies, Geneva, and Drs. Cumston and Maillart, for the trouble they have taken in obtaining information about Jallabert; Professor Fleming, of University College, London, for the illustration of Faraday's ring; Mr. C. H. Golding-Bird, for the photograph of the bust of his father in Guy's Hospital Medical School; Dr. Cumberbatch, for the portraits of Steavenson, Lewis Jones and Rühmkorff; Mr. Hurry Fenwick, for kind permission to use the illustrations from his *Electric Illumination of the Bladder* (Churchill); Dr. Wertheim Salomonson, for the illustrations of his apparatus and the prints from actual negatives of the fundus oculi; Dr. Wiltshire, of King's College Hospital, for the picture of the electrocardiograph. The proprietors of *Punch*, for permission to reproduce Mr. E. T. Reed's picture anent the "New Photographic Discovery"; Dr. Meek, of Newcastle-on-Tyne, for the reproduction of the skiagram of *Astropecten*; Professor Waymouth Reid, for the skiagram of the frog; Dr. Rodman, for the pictures of X-ray tubes; Dr. Knox, for the skiagram of gall stones; Mr. Thomson Walker and Dr. Knox, for the pyelogram; and the Editors of *Le Radium*, *The British Medical Journal*, *Nature*, *The Photographic Journal*, and the *Archives of Radiology*, for their kind

courtesy in allowing me to reproduce illustrations from their respective journals.

As regards the actual preparation of the work for the press, I have to thank Dr. F. E. Taylor, of King's College, London, for his kindness in reading through the proof sheets and for many valuable suggestions; my wife for a large number of photographic reproductions from older works; Mr. Powell, the Librarian of the Royal Society of Medicine, for his kindness in hunting up all kinds of material—often, I am afraid, at considerable personal inconvenience; Mr. Forder, Radiographer at King's College Hospital, for many photographs; and Sister Slater, of the X-ray Department, King's College Hospital, for compiling the index.

King's College Hospital, London.
January, 1922.

ILLUSTRATIONS

Since going to press I have found the following lines, nominally written by Miss Anna Williams, but which Dr. Johnson said he had rewritten, "all except two lines." Miss Williams was the daughter of Zachariah Williams, M.D. (1673 ?-1755), who after the failure of his schemes for "ascertaining the longitude by magnetism," was admitted a poor brother of the Charterhouse. Here commenced an intimacy with another inhabitant of the Charterhouse, Stephen Grey, F.R.S., who was busied with his electrical experiments. Williams, in defiance of all rules and regulations, had his daughter to live with him in the Charterhouse for two years, a breach of discipline which was one of the reasons given for his expulsion. While residing in the Charterhouse, Miss Williams helped Grey in his electrical experiments, and claimed to be the first who saw a spark drawn from the human body. She subsequently became blind through cataract, and, as an inmate of Dr. Johnson's queer household, is a familiar figure to all readers of Boswell.

ON THE DEATH OF STEPHEN GREY, F.R.S., THE AUTHOR OF "THE PRESENT DOCTRINE OF ELECTRICITY."*

Long hast thou born the burthen of the day,
Thy task is ended, venerable GREY!
No more shall Art thy dext'rous hand require
To break the sleep of Elemental fire;
To rouse the powers that actuate Nature's frame,
The momentaneous shock, Th' electrick flame,
The flame which first, weak pupil of thy lore,
I saw, condemn'd, alas! to see no more.

Now, hoary Sage, pursue thy happy flight,
With swifter motion haste to purer light,
Where BACON waits with NEWTON and with BOYLE
To hail thy genius, and applaud thy toil;
Where intuition breaks through time and space—
And mocks experiment's successive race;
Sees tardy Science toil at Nature's laws
And wonders how th' effect obscures the cause.

YET not to deep research or happy guess
Is ow'd the life of hope, the death of peace.
Unblest the man whom philosophick rage
Shall tempt to lose the Christian in the Sage;
Not Art but Goodness poured the sacred ray
That cheer'd the parting hour of humble GREY.

* The Publisher of this miscellany, as she was assisting Mr. Grey in his experiments, was the first that observed and notified the emission of the electrical spark from a human body.

AN ESSAY ON THE HISTORY OF ELECTROTHERAPY.

If we limit the term electrotherapy to the treatment of disease by scientifically standardised electrical apparatus, its history is clearly a very short one ; if, on the other hand, we consent to include under that term the employment of remedial agents, whose real or supposed efficiency depends upon electrical phenomena, it can claim an antiquity as great as any branch of medical science. Needless to say, in this latter case the data are few, the diagnoses of the same value as those in most other branches of medicine of equal antiquity, while the apparatus was derived not from the laboratory of man, but from Nature.

The use of medicinal springs dates, of course, from time immemorial, and if in some cases these derive a part, at any rate, of their efficacy from the presence of radio-active substances, we are faced with the paradox that not only electrotherapy, but radiotherapy itself, must rank among the remedial measures of antiquity, and was employed centuries before the term electricity was ever invented. Equally curious, at first sight, is the fact that the first source of static electricity employed in the treatment of disease was a living animal, the torpedo, an elasmobranch fish of the ray family, common in the Mediterranean and in tropical seas. From the earliest times the inhabitants of the neighbouring regions were accustomed to bathe their children in water in which one of these fishes was placed ; nor are classical writers silent about the value of its shocks in cases of paralysis, cramp, painful affections of the joints, and various disorders commonly regarded as nervous in origin.

Anthero, a freedman of the Emperor Tiberius, was reported by Scribonius Largus to have been cured of gout by placing his foot upon a live torpedo by the seashore. Dioscorides recommended shocks from the torpedo as a remedy for

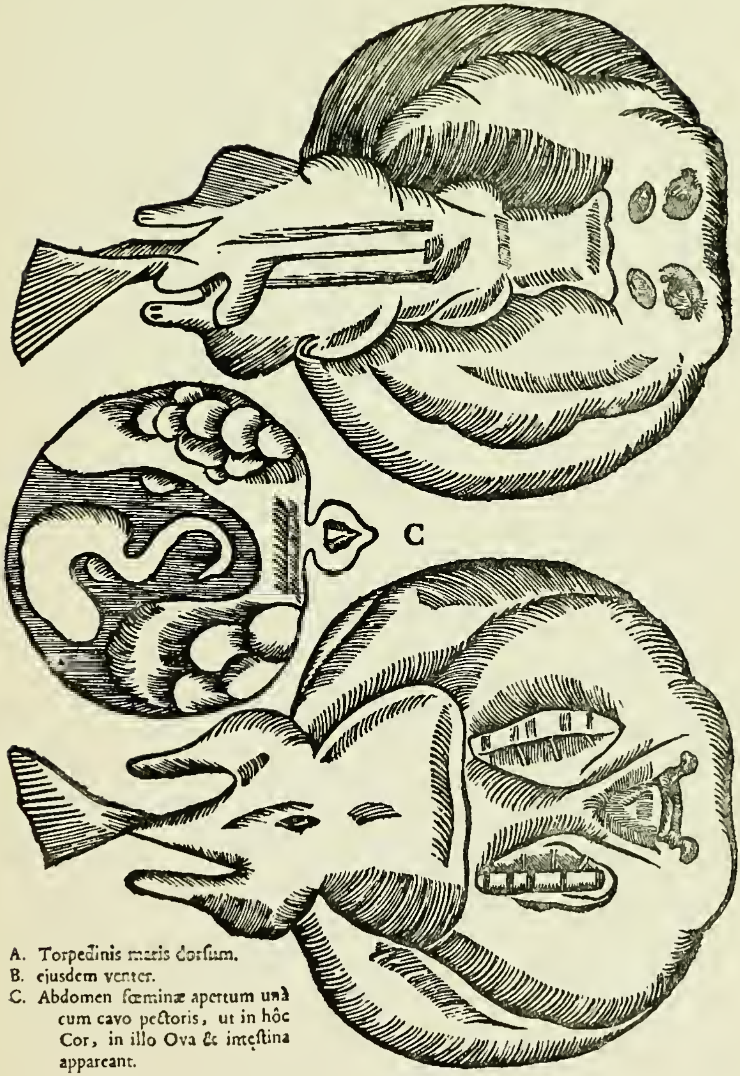
intractable headaches, a prescription in which he was followed by Galen, and later by Paul of Ægina (625-690). Pliny, in his "Natural History," refers to the torpedo in terms which imply that it was well known as a therapeutic agent, thus: "From a considerable distance, even, and if only touched with the end of a spear or staff, this fish has the property of benumbing even the most vigorous arm, and of riveting the feet of the runner, however swift he may be in the race. If, upon considering this fresh illustration, we find ourselves compelled to admit that there is in existence a certain power, which by the very exhalations, and, as it were, emanations therefrom, is enabled to affect the members of the human body, what are we not to hope for from the remedial influences which Nature has centred in all animated beings?"

In another passage Pliny informs us that, if a torpedo is caught at the time the moon is in Libra, and kept in the open air for three days, it will facilitate childbirth if introduced into the room of a woman in labour.

According to Coldstream, who contributed an article on Animal Electricity to Todd's *Cyclopædia of Anatomy and Physiology* (1836-1839), the torpedo was still employed among the Arabs at that time. In this case the method of treatment was somewhat modified, the patient being placed naked upon a table while the fish was applied to different parts of the body in succession; the author adds that "this treatment causes rather severe suffering, but enjoys the reputation of being febrifuge."*

The true character of the shocks given by the torpedo was not elucidated till 1772, when Dr. John Walsh published the results of his observations, and proved them to be identical in character with those obtained from an ordinary electrical machine. In the same year John Hunter dissected the fish, and described the anatomy of its electrical organ, while in 1773 Ingenhousz, of Vienna, independently made observations similar to those of Walsh, and arrived at the same conclusion. Previously to these observers, the illustrious Italian scientist, Francesco Redi, had in 1666 obtained specimens of the torpedo, and experienced their shocks, while he was, more-

* See Note A, p 173.



Torpedo.
(Kæmpfer's *Amœnitatum Exoticarum*, 1712)

over, the first to dissect them, and to furnish a brief description of the electrical organ. Réaumur also described the shocks, which he erroneously ascribed to sudden muscular action. Kaempfer, in 1712, compared the sudden stroke of the torpedo to lightning, but inaccurately added that by holding the breath the observer was prevented from feeling the shock.

For purposes of completeness, we may add a brief account of some of the early observations upon the *Gymnotus electricus*, or electric eel of South America. So far, however, from its being employed by the natives as a therapeutic agent, it was regarded by them with terror. The earliest European accounts of this fish seem to have been those of de la Condamine, who noticed its extraordinary powers, and described it under the title of "une espèce de lamproi." Far more extensive were the observations of Bancroft in his *Natural History of Guiana* (1769); he furnishes a good description of the creature, compares its shock to that of electricity, and proposes the name of "Torporific Eel." Humboldt and Bonpland, during their travels in Guiana, in 1800, were desirous of obtaining specimens, and furnished vivid descriptions of the difficulties attending their capture, since the natives had such a terror of the Gymnoti, that for a long time they could not be persuaded to make any attempt. Eventually they procured about thirty horses, and by driving them into the pond containing the fish the unfortunate horses received the shocks from the eels, which were then captured in a state of exhaustion. Some idea of the force of the shocks may be gathered from the fact that in less than five minutes two horses were drowned, while all exhibited signs of terror and agony.

Communications in which the electrical nature of the discharge was established were made in 1775, by Dr. Garden, of Charlestown, while dissections were again undertaken by John Hunter.

As another form of primitive electrotherapy may be mentioned the use of the lodestone in the treatment of disease. There is, however, an obvious difference between the employment of such a source of natural electricity as the torpedo, which, whatever the merits or demerits of the proceeding may

have been, did at any rate administer a genuine electric shock, and the therapeutic use of the natural magnet or lodestone. In the latter case there was obviously no shock, and apart from its properties as a compound of iron, any influence it may have had must have been exerted through the imagination of the

John Hunter.

patient. Indeed, the employment of the lodestone in medicine really comes under the heading of what is known to anthropologists as sympathetic magic. The obvious characteristic possessed by the mineral in question, of attracting iron, was held to indicate the possession of powers of attracting or repelling the causes of disease ; superstitions concerning them

were, as may be imagined, extremely common, while accurate observations were reduced to a minimum.* Pliny records that iron could be magnetised by the lodestone, and adds that wounds inflicted by a weapon so treated were particularly severe. Lodestones triturated and calcined were employed in ophthalmic preparations, and as an application for burns. The ancients cherished an absurd superstition, again recorded by Pliny, to the effect that natural magnets were of different sexes : "The leading distinction is the sex, male and female, and the next great difference in them is the colour. One found in Troas is black, of the female sex, and consequently destitute of attractive power." The most highly esteemed variety was the Ethiopian, which was purchased for its weight in silver. These extraordinary assertions regarding natural magnets did not decrease during the middle ages, and according to a recent writer, Dr. Fernie, there is still a considerable sale of small pieces of magnetic iron oxide for use as amulets. Among other virtues the lodestone was recommended for cramp and gout, and was reputed to be efficacious in reconciling estranged husbands and wives. As an example of the nonsense which could be written by a learned man about the magnet, may be quoted an extract from van Helmont (1557-1624). Van Helmont was an alchemist ; in many ways he was a shrewd observer, but it would be difficult to find passages in which real and imaginary phenomena are more confused than the following : "The back of the lodestone, as it repulseth iron ; so also it drives back the Gout, cures Burstness and every catarrh or rheum which is of the nature of iron." Again, according to the same writer, the power of the lodestone is lost if it be rubbed with garlic, a statement which one would have thought could have been verified or refuted without the expenditure of an abnormal amount of experimental ingenuity.†

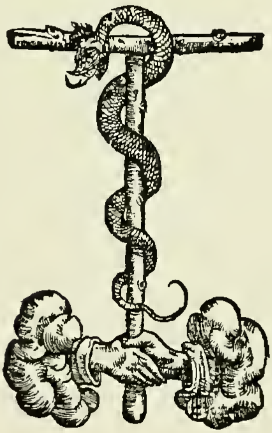
* On Christmas Eve, 1920, I saw in a druggist's shop window some bottles of "tonic," which was described as being prepared from Magnetized Iron. This was in London, not a mile from Victoria Station.

† Addison (*Spectator* No. 56, May 4th, 1711) mentions a statement by Albertus Magnus, that fire would cause a lodestone to lose its properties, and that he took particular notice of one, as it lay among the burning coals, observing a blue flame to rise from it. This he conceived to be, possibly, the essential powers of the lodestone leaving it. See Note B., p. 173.

Otto von Guericke.

GVILIELMI GIL
BERTI COLCESTREN-
SIS, MEDICI LONDI-
NENSIS,

DE MAGNETE, MAGNETI-
CISQVE CORPORIBVS, ET DE MAG-
no magnete tellure; Physiologia noua,
*plurimis & argumentis, & expe-
rimentis* demonstrata.



LONDINI

EXCVDEBAT Petrvs Short ANNO
MDC.

Title page of Gilbert's *De Magnete.* (Reduced, the original size is *Folio.*)

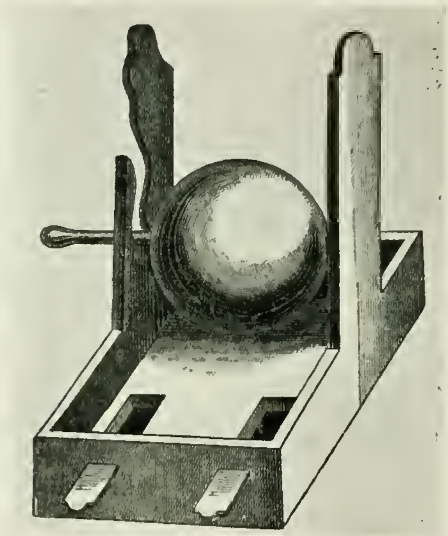
It was not likely that any progress could be made in physics while such inextricable confusion of ideas prevailed, and the first beginnings of the modern science of electricity are due to William Gilbert (1540-1603), President of the Royal College of Physicians, Physician to Queen Elizabeth, and afterwards to James I, although he died in the year of the latter monarch's accession. It is a caustic instance of the irony of fate that one of the most pedantic buffoons who ever occupied a throne should have had his court honoured with the presence of two of the founders of modern experimental science—Francis Bacon and William Gilbert. In the year 1600, Gilbert published his work, *De Magnete*, which laid the foundation of modern conceptions of electricity. He was the first to show that other bodies besides amber and jet could be electrified by friction, while the term "electric," or rather its Latin equivalent, was first used by him in the treatise in question.* Queen Elizabeth took a keen interest in Gilbert's work, and granted him a pension; and, indeed, he seems to have had the good fortune, only too rare with pioneers of science, to have been appreciated at his true value during his lifetime. He bequeathed his books and scientific apparatus to the Royal College of Physicians; unfortunately they were destroyed in the Great Fire of 1666.

While the apparatus at the disposal of electricians consisted solely of small fragments of amber† and sulphur, which attracted light bodies when rubbed, it was clearly impossible for any save the most elementary truths to be established, and the next great step in electrical knowledge was the making of a primitive electrical machine by Otto von Guericke about the year 1650. His "machine" consisted merely of a globe of sulphur, furnished with an axis and mounted in a frame, while the application of his own hand supplied the necessary friction.

* The word occurs in the passage, "Vim illam electricam nobis placet appellare quæ ab humore provenit." In the glossary to *De Magnete* the following occurs: "Electrica, quæ attrahunt eadem ratione ut electrum." According to Prof. Silvanus Thompson, the noun Electricity was first used by Charleton in his *Ternary of Paradoxes*, translated from van Helmont. The first work in English upon the subject is a scarce pamphet by the Hon. Robert Boyle, published in 1675, and entitled, *Experiments and Notes about the Mechanical Origine or Production of Electricity.*

† See Note C, p 174.

With this crude machine he was able to see the electric spark, and to observe the curious crackling sound which accompanies it. Much better sparks, however, were obtained later by Dr. Wall, who employed a rod of amber rubbed by a woollen cloth, and at the same time noted that "this light and crackling seem in some degree to represent thunder and lightning." The actual demonstration of the electrical origin of lightning was established in 1749, by Benjamin Franklin.

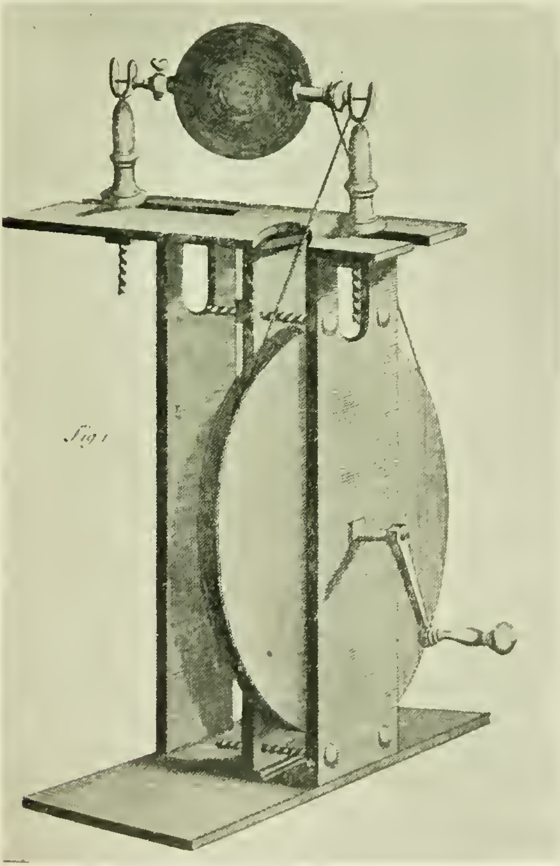


Von Guericke's sulphur ball.

Hauksbee, in 1709, substituted a glass globe for von Guericke's globe of sulphur, although, as a matter of fact, the original sulphur globe was cast inside a glass vessel, which was subsequently broken. After a comparatively short time these electrical machines, in both of which the hand was used as the rubber, were discarded in favour of rods of amber, glass, sulphur, and sealing wax. The introduction of a rubber * as part of the apparatus was due to Giessing, a co-worker with

* There was some difficulty in adjusting the rubbers to the globes, and the hand was very generally used as a rubber. Owing, however, to the globes breaking, in some cases with almost explosive violence, the rubbers became more general.

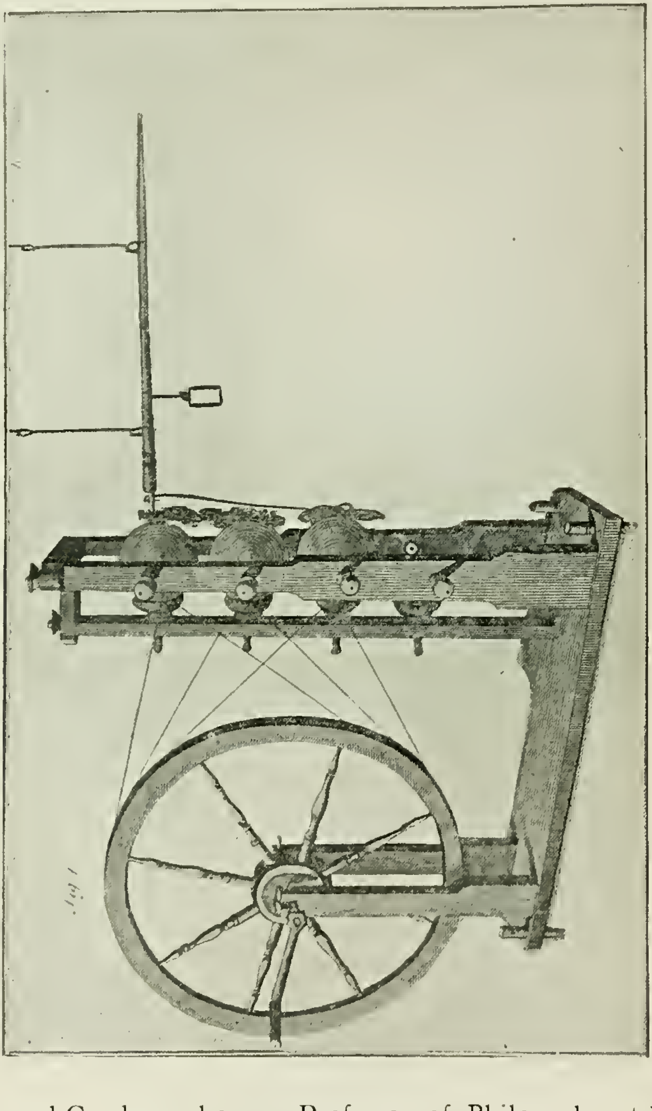
Winckler, of Leipzig, while for the first conception of a prime conductor we are indebted to Bose, who employed an iron tube held by an assistant standing upon cakes of resin. Subsequently the tube was suspended by silk threads, either from the ceiling or from some suitable framework.



Hauksbee's Electric Machine. (From Priestley's *History of Electricity*, 3rd Ed., 1775.)

The essential parts of a frictional electric machine having been thus evolved, investigators, especially in Germany, sought to obtain an increased electrical discharge by multiplying the number of globes which could be rotated in one machine. The globes were commonly detachable from the machine,

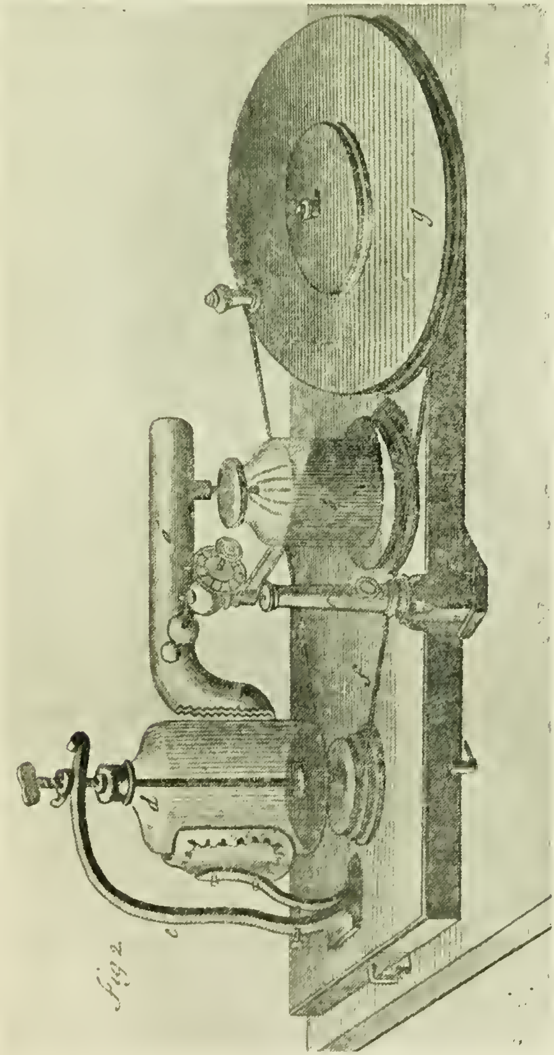
so that their number could be varied at will. The substitution of glass cylinders for globes was due to a Scotch Benedictine



Dr. Watson's machine, constructed for four globes, three of which are shown in position. The conductor is seen on the right, suspended by silk cords; the rubbers are on the immediate left of the globes. (From Priestley's *History of Electricity*, 3rd Ed., 1775.)

named Gordon, who was Professor of Philosophy at Erfurt; an early cylinder machine, specially designed for medical purposes, is shown in the accompanying cut, as is also a

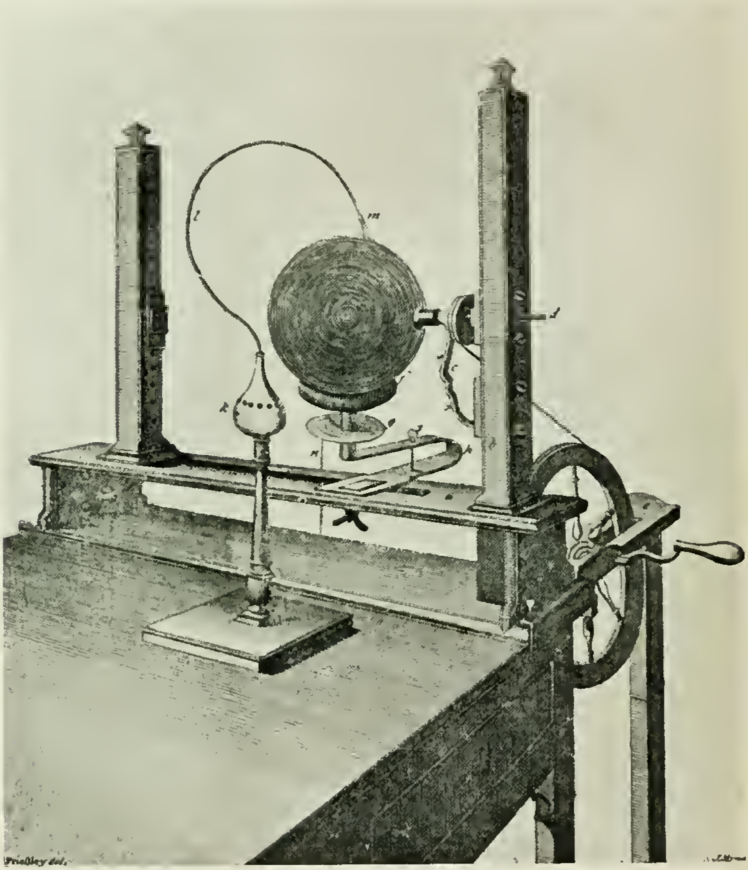
machine built to the specification of the celebrated Priestley in the figure following. These figures are taken from Priestley's



Read's cylinder machine, specially constructed for medical purposes: (*a*) The conductor, connected with the coated jar (*b*); (*c*) is a Lane's electrometer; (*d*) the cylinder. (From Priestley's *History of Electricity*, 3rd Ed., 1775.)

work on the "History of Electricity" (3rd Ed., London, 1775), a book which well deserves reading, not only because of the interest of its subject matter but also on account of its charm of style.

The Leyden Jar, which plays an important part in some of the early experiments in electrotherapeutics, was discovered by von Kleist, Dean of the Cathedral of Camin, in 1745. An apparently independent discovery of the same kind was made



Priestley's machine, fitted with adjustable supports for globe and rubber. The conductor (*k*) collects the electricity by the flexible wire (*l*), and is furnished with a series of perforations to allow of the introduction of wires for experimental purposes. (From Priestley's *History of Electricity*, 3rd Ed , 1775.)

by Cuneus and Musschenbroek at Leyden, in 1746, and although the priority unquestionably belongs to von Kleist, the piece of apparatus became known as the Leyden Jar. It

is of interest to read the records of some of the early experiments on the action of electricity upon the human subject, since we are able to repeat them ourselves, and to compare our own observations with the accounts given by the early

Pieter van Musschenbroek.
(From a bust in the University of Utrecht.)

observers. Thus Musschenbroek, in communicating to Réaumur the account of the shock he received from his very primitive Leyden Jar, states that he felt himself struck in the arms, shoulder and breast; he lost his breath, and it was two days before he recovered from the shock and fright. He

added that not for the Crown of France itself would he expose himself to such another experience.

The most extravagant description of the effects of a shock

Pieter van Musschenbroek.

from a Leyden Jar is that of Winckler, which is given by Priestley thus: "The first time he tried the Leyden experiment, he found great convulsions by it in his body; and that it put his blood into great agitation, so that he was

afraid of an ardent fever and was obliged to use refrigerant medicines. He also felt an heaviness in his head, as if a stone lay on it. Twice, he says, it gave him bleeding at the nose."

As regards the earliest experiments upon the effects of electricity on the human subject, it is clearly difficult to assign definite priority, since the first rubber for the sulphur or glass globe was the operator's own hand. In 1730 Stephen Grey suspended a small boy by hair cords, and on bringing a charged tube near his feet found that the lad's head attracted scraps of copper leaf, thus demonstrating the phenomenon of electrification by induction. The first to draw sparks from an electrified human being was Du Fay, a physician, and superintendent of the royal gardens in Paris. Du Fay caused himself to be suspended by silken ropes, and while in this situation to be electrified. Upon the approach of the hand of another person sparks were observed, to the surprise of both Du Fay himself and of the Abbé Nollet, who was also present.

The first recorded observation of the use of electricity for a specifically medical purpose is that of Kratzenstein, Professor of Medicine at Halle, the patient being a woman who suffered from a contraction of the little finger; after a quarter of an hours electrification the condition was reported as cured. Whatever the permanent effect on the finger may have been, Kratzenstein also noted the acceleration of the pulse-rate as a sequel to electrification.

Jallabert,* Professor of Physics at Geneva, must be regarded as the first scientific electrotherapist, although his work in this direction has not always received its due appreciation. In 1747 he effected some improvement in a locksmith, whose arm had been paralysed for fifteen years, the exciting cause being recorded as a blow from a hammer. As the man was also lame in the leg of the same side, it seems probable that the case was one of genuine hemiplegia. Jallabert, who worked in conjunction with the surgeon Guyot, also of Geneva noticed that when sparks were drawn from the affected arm the individual muscles underwent contraction, and he purposely attempted to produce these muscular contractions with a view to producing exercise of individual muscles, through the un-

* See Note D. p. 175.

broken skin. Some of his observations are so interesting that they deserve quotation in detail.*

"Un effet de l'électricité, qu'il n'est pas indifferent de remarquer, c'est que l'on aperçoit dans les muscles d'où l'on tire les étincelles, divers mouvements convulsifs. Je les ai souvent observés dans les muscles du carpe et des doigts de la main d'un bras paralytique, et suivant que je tirais l'étincelle des muscles extenseurs et fléchisseurs, ces parties quoique privées de sentiment et de mouvement depuis longtemps, se mouvaient à ma volonté, d'une manière très marquée."

He and Guyot kept a regular history of the treatment of the locksmith, in which the treatment and progress of the patient were recorded from day to day.

"Je plaçai le malade, le bras nu sur de la poix ; et l'ayant fait vivement électriser, j'approchai le doigt des muscles qui couvrent les os de l'avant bras. Non seulement les étincelles que j'excitai furent très vives, mais nous observâmes des mouvements couvulsifs et très pressés dans le muscle dont on les tirait ; et le poignet, le carpe et les doigts étaient diversement agités.

"Ainsi ce poignet et ces doigts, privés de tout mouvement volontaire, se mouvaient à mon grè selon le muscle auquel je presentais de doigt. Ce phenomène méritait sans doute le plus serieux examen.

"Je me mis à la place du paralytique, et M. Guiot en presentant le doigt à mon bras causa dans mes muscles et dans les parties solides les mêmes mouvements que nous avions observés dans le paralytique. J'étendais et fléchissais le carpe et les doigts selon la nature du muscle d'où partait l'étincelle, sans qu'il fut en mon pouvoir d'en arrêter les mouvements.

"J'ai éprouvé dans la suite que, malgré les efforts d'une personne placée de même que moi sur de la poix, les étincelles tirées par exemple, des muscles extenseurs et abducteurs, ou du long fléchisseur du pouce, l'obligeait d'écarter ou d'approcher le pouce de la paume de la main, ou d'en fléchir la troisième phalange."

And further, as showing that Jallabert was fully cognisant of the nature of the contractions, we may note the following significant passage:—

"Cette méthode d'agir sur les muscles (en tirant des étincelles) m'a paru propre à donner une idée générale de la myologie. En même temps qu'on indique un muscle, ses oscillations indiquent à l'œil l'usage par l'agitation de la partie solide à laquelle il est attaché. Je ne sais même si, dans quelques cas, ces expériences ne seraient point plus sûres que celles qu'on fait en tirant les muscles disséqués d'un cadavre."

* The quotations from Jallabert's notes are taken from an article by Dr. Paul Ladame, of Geneva, in the *Revue Médicale de la Suisse Romande*, 1885.

Jallabert continued his experiments on local muscular stimulation, and subsequently made use of a small iron rod with a rounded end for drawing the sparks. From these facts it will be seen that he was the precursor of Duchenne, who published his results a century later, and who used the induced current for effecting his muscular stimulation. To Jallabert must therefore be conceded the honour of being the first scientific electrotherapist. The giving of severe shocks from Leyden Jars, promiscuous electrification and spark-drawing, are methods of treatment which offer wide and manifest differences from the carefully thought-out work of Jallabert and Guyot. The small recognition given to him in recent years is probably due in no small measure to the Abbé Nollet, who found the locksmith was not permanently cured, and who, moreover, was inclined to be in a highly sceptical mood, from his critical investigations upon certain alleged phenomena, which we must now describe.

The years 1747 and 1748 are interesting in the history of electrotherapy from some extraordinary claims which originated in Italy, and were reported to be confirmed in Germany. That they were deliberate cases of fraud one is unwilling to believe; though by what process of self-delusion the observers arrived at their conclusions it is difficult to understand. In this connection, however, it may be well to bear in mind the early records of the effects of a shock from a Leyden Jar.

The ball was set rolling by Pivati, of Venice, Keeper of the Library, and member of the Academy of Bologna. It may be well here to examine the chain of reasoning which Pivati followed in his experiments. In the first place, he was acquainted with the fact that electrification of an individual accelerates his pulse-rate ; from this he concluded that the subtle electric fluid could penetrate the whole human body, even reaching to the heart. He next turned his attention to the electrification of all kinds of natural objects, minerals, fossils (at that time a rife source of wonder and speculation), and flowers. On electrifying a vase of flowers, and allowing a spark from the electrified system to enter his nostril, he observed both the odour of the flower and a peculiar "nitrous smell." That he should smell a perfumed flower placed close

to his nose is not surprising, while the smell accompanying a sparking electrical discharge was very fairly described as "nitrous." Pivati, however, imagined that the perfume of the flower was carried by the electrical discharge to his nose, and that since the electric fluid could penetrate all parts of the body, as shown by its action on the heart, it would carry volatile substances along with it, and thus serve as a means of administering drugs without the usual preliminaries of tasting and swallowing them.

So far, the line of thought is fairly clear and coherent. Pivati's next step was to enclose some Balsam of Peru in a glass cylinder, which he alleged to be hermetically sealed, and to emit no odour even when warmed. Upon electrifying the cylinder by friction the case was different, and the odour of Balsam of Peru was declared to pervade the room. A man who suffered from a pain in the side was electrified by use of this prepared and sealed cylinder, he himself being ignorant of the nature of its contents. The recorded result of this treatment is, to say the least of it, surprising. The patient went home, fell asleep, broke into a profuse perspiration, and his clothing and bedding all exhaled the odour of Peruvian Balsam; in order that nothing might be wanting to carry conviction to the most sceptical, it was recorded that the comb he had used was similarly perfumed.

On the following day Pivati electrified a normal individual with the same tube, the subject being again ignorant of its contents. The recorded result was, that about half an hour afterwards he felt a gradual warmth pervading his body, he became unusually lively, and exhaled the odour of Balsam of Peru.

Pivati had a more distinguished patient, the Bishop of Sebenico. This poor old gentleman was so afflicted with gout that he was unable to move either his hands or his knees. After two minutes treatment he opened and shut his hands, shook hands with his attendants, and walked downstairs like a young man!

Winckler (already mentioned as the hero of a Leyden Jar experiment) also performed some experiments upon similar lines. In one of these he introduced sulphur into a glass

sphere, which was then carefully sealed, so that upon heating no odour of sulphur was perceptible. Upon electrifying the cold sphere, he recorded that a strong smell of sulphur pervaded the room, and on continuing the electrification the smell became so intolerable that the bystanders were compelled to withdraw. Winckler relates that he himself remained, and that his body, clothes, and breath smelt of sulphur all the next day. On repeating the experiment, the "signs of an inflamed blood were visible in his mouth on the third day."

Bianchi,* Professor of Medicine at Turin, also claimed to have observed that purgatives, such as scammony, held in the hand of a person during electrification, produced the same effects as when administered by the mouth, and similar results were claimed by Veratti, of Bologna.

These extraordinary claims were investigated by the Abbé Nollet, who journeyed to Italy for the purpose. After visiting the various experimenters, he came to the conclusion that there had been gross exaggeration in the accounts of their cures, and in no single instance was he able to substantiate the permeability of glass to volatile substances under electrification. The sceptical frame of mind which these investigations produced, doubtless had their effect in leading him to underestimate the value of the work of Jallabert.

Winckler sent an account of his results to the Royal Society, The experiments were repeated, but without success. The Royal Society accordingly requested him to send over some of his own apparatus, which he forthwith did. On the 12th of June, 1751, a Committee of the Society met at Dr. Watson's house, and again repeated the experiments with Winckler's own apparatus, but here again complete failure resulted.

Owing to the limited character of the electrical appliances then available, the legitimate electrotherapy of the eighteenth century was confined to either insulating the patient, electrifying him, and then drawing sparks from the affected part, or to the administration of shocks, usually by means of one or more Leyden Jars, though, as we have said, Jallabert and Guyo.

* In view of certain similarities between the names, the work of Bianchi must be clearly distinguished from that of Bianchini and of Bianconi, Physician to the Prince of Aosta. Both these observers repeated the experiments of Pivati, and were totally unable to corroborate them.

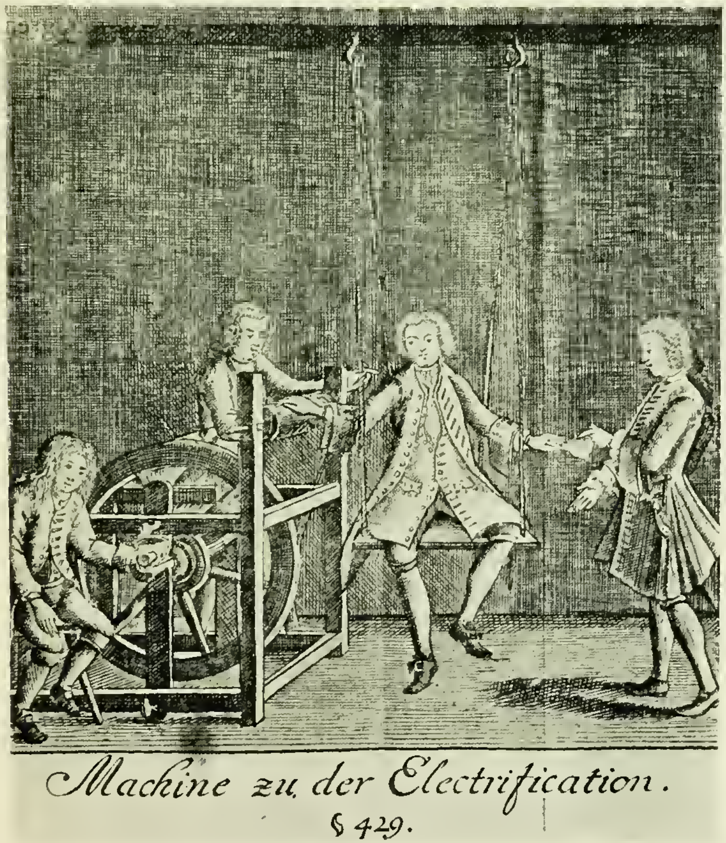
were the only workers whose methods could be regarded as scientific.

Among the early workers in this field, two are of especial interest—John Wesley and Benjamin Franklin. Wesley, as is well known, was fond of dabbling in medicine, and seems to have acted as a kind of medical adviser to the members of his congregation. Priestley, in his *History of Electricity*, states

Sir William Watson.

"Mr. Wesley's people, I believe, generally use a machine in which two cylinders are turned by the same wheel; but one that I saw, in the possession of a very intelligent member of that persuasion, had the cylinders and rubbers so confined in a chest, that, though it might do very well for medical uses, it was very ill adapted to the purposes of philosophy." Priestley, nevertheless, had a high opinion of Wesley's electrotherapeutic measures, as the following passage bears witness: "The Rev.

Mr. J. Wesley has followed Mr. Lovet in the same useful course of medical electricity, and recommends the use of it to his numerous followers and to all people. Happy it is when an ascendency over the minds of men is employed to purposes



From Kruger's *Naturlehre*.

favourable to the increase of knowledge, and to the best interests of mankind."

In 1759, Wesley published a little work, entitled *The Desideratum*, in which he sets forth descriptions of some electrical phenomena, and recommends the use of electricity as a therapeutic agent. This little book is therefore one of the earliest publications upon the subject in the English language.

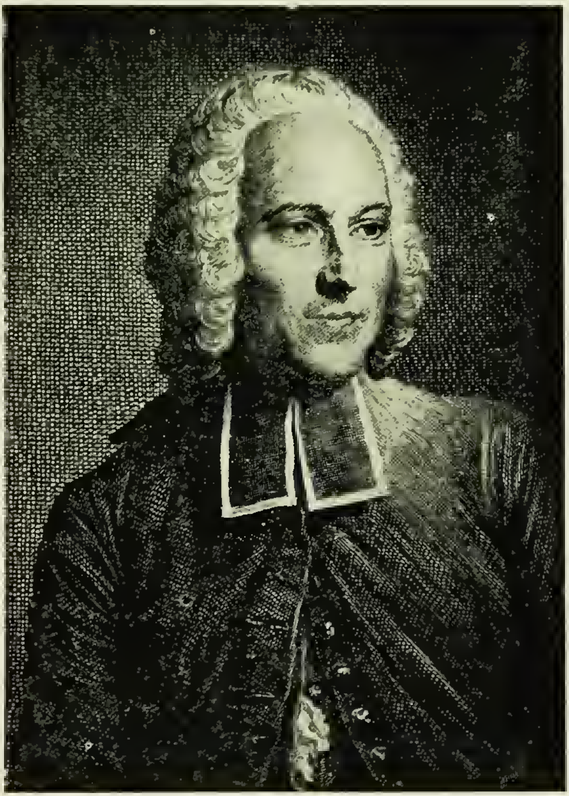
Among the earliest publications—if indeed it was not the first—by an English medical man on the subject, was one written in Latin by Dr. Robert Steavenson, Physician to the Infirmary at Newcastle-on-Tyne, and published in 1778. It was entitled *Dissertatio Medica Inauguralis, de Electricitate et Operatione ejus in Morbis Curandis*, and its author was great-uncle to Dr. W. E. Steavenson, the first of the modern Electrical Medical Officers at St. Bartholomew's Hospital.

The earliest continental work on medical electricity was *De hemiplegia per electricitatem curanda*, written by Deshais, and published at Montpellier, in 1749, and in 1751 appeared *De utilitate electrisationis in Arte Medica*, which was written by Bohadsch and published at Prague.

Franklin records his observations in a letter dated December, 1757, and addressed to Sir John Pringle, by whom it was communicated to the Royal Society. After referring to the fact that the newspapers contain accounts of great cures performed in Italy and Germany, he proceeds to an account of some of his own cases. "People were brought to me from different parts of Pennsylvania and the neighbouring provinces to be electrified; which I did for them at their request. My method was to place the patient first in a chair, on an electric stool, and draw a number of large sparks from all parts of the affected limb or side. Then I fully charged six two-gallon jars, each of which had about three square feet of surface coated ; and I sent the united shock through the affected limb or limbs ; repeating the stroke commonly three times each day." At first some improvement was noted, but Franklin records that he never saw any improvement after the fifth day, a fact which was also noted by the patients themselves, who, either through disappointment or from the unpleasant severity of the shocks, usually returned home and did not apply for further treatment. Franklin's letter, as may be anticipated from his general character, is a model of candour, and stands in marked contrast to the exaggerated statements of Pivati, Winckler, Bianchi, and certain other workers about this time. He freely admits that he doubts whether the temporary improvements were due to his treatment, or to the excerise necessitated by the walk to his house, and adds that he wishes

the advice of a skilled physician could have been obtained to direct the treatment, administer suitable medicines, and attend to the patients' general condition.

The Abbé Nollett also admits that during an experience of fifteen or sixteen years he had not known of a permanent cure

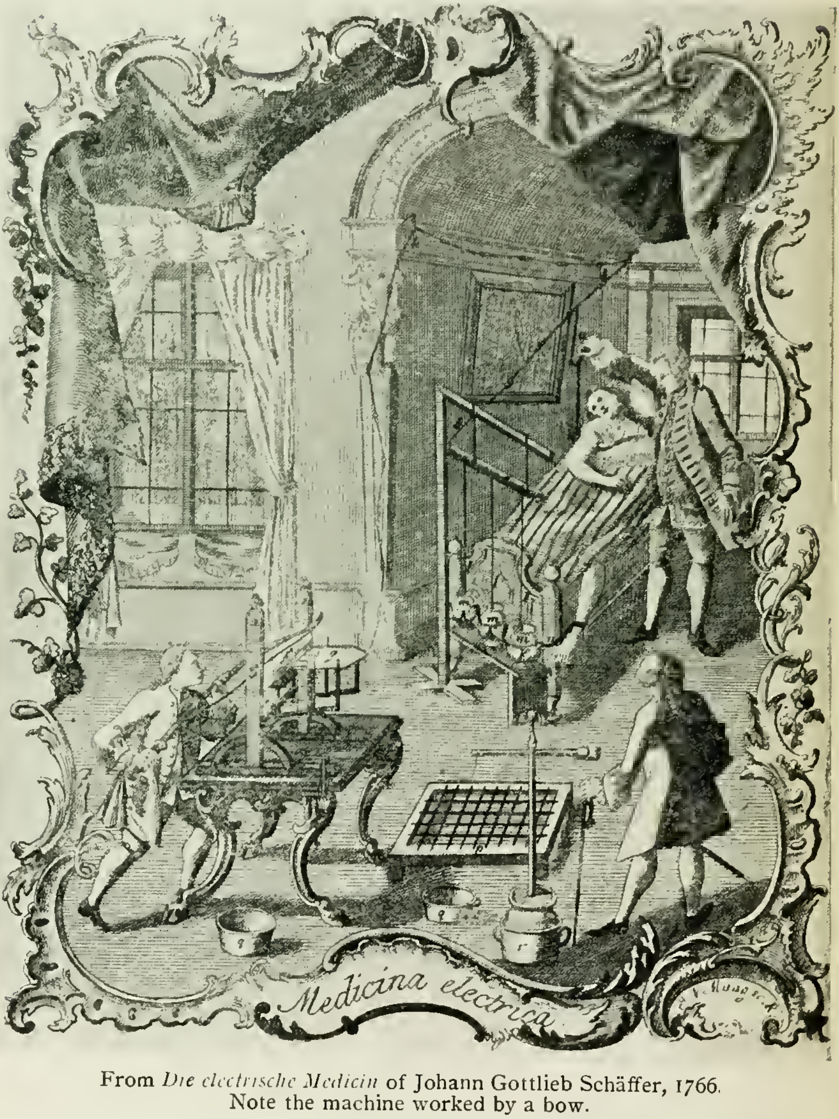


Abbé Nollett.

from electrification, though he adds that he had also not noticed any ill effect.

That no ill effect was recorded from electrification is a little remarkable, in view of the powerful shocks given and the stupid methods of administering them. Thus, in 1755, Leroy published the accounts of some experiments conducted by him upon a youth suffering from amaurosis. The shock used was from a Leyden Jar, the coatings of which were connected to

two wires, one wound round the patient's head and the other round his leg. With each discharge of the jar the blind man



From *Die electrische Medicin* of Johann Gottlieb Schäffer, 1766. Note the machine worked by a bow.

saw a flame passing before his eyes, and heard a report like that of a gun. On sending the shock through his head from

before backwards (one metal plate being fixed on his forehead, the other on the occiput, and then connected as required to the jar), the patient reported that each shock caused him to see crowds of people and such-like appearances. Precisely what induced the patient to endure this is not at once obvious, but probably the visual impressions suggested the possibility of recovery of sight.

In England, Patrick Brydone, although not a medical man, added amateur electrotherapy to his other accomplishments, and, in 1757, published a tract on *An Instance of the Electrical Virtue in the Cure of a Palsy.* In this instance, the operator chronicles the administration of six hundred severe shocks.

The credit of first protesting against these violent shocks is due to Richard Lovett (1692-1780). Lovett, again, was not a medical practitioner, being in fact a lay-clerk of Worcester Cathedral. He was the author of several amateur scientific tracts, and among them of the *Subtil Medium*, published in 1756. It is in this book that Lovett expresses a kind of mild surprise at some patients refusing to continue treatment owing to the pain consequent upon the severity of the shocks administered, adding that he himself never employed any which could be described even as uncomfortable.

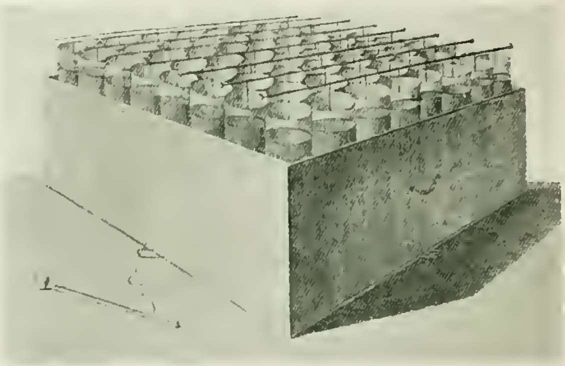
In the *Subtil Medium* he informs us that he had been studying electricity for some five or six years, which would make him about sixty years old at the time of starting his studies, so we can picture him as a well-meaning old fellow, pottering about his cathedral city of Worcester, administering electric shocks where he thought they would be useful—in some cases, I fear, without the knowledge of the medical attendants, but seeming on the whole to have been generally well thought of and kindly received.

In the earlier history of the development of electrotherapy, records of animal experiments—apart from the empirical treatment of human beings—are relatively few. In the great majority of cases such experiments consisted in killing an animal by means of a shock from a battery of Leyden Jars, and then making a *post-mortem* of the remains.

Priestley gives details of some of his own experiments; the animals experimented upon varied from a small field mouse to

a good-sized dog. The mouse was killed by a discharge from a battery with a coated surface of thirty-six square feet; the dog received the shock from a battery with sixty-two square feet, coated; it was not however killed outright, but knocked senseless and blinded.

The phenomenon of muscular contraction, as the result of electrical stimulation, was, as we have seen, first noticed by Jallabert, of Geneva, in 1748. The contraction of an isolated muscle, as the result of the electric stimulus, was noticed by Beccaria, about 1758. In this case, one of the thigh muscles of a living cock was exposed and separated; upon electric stimulation strong contractions were observed. Beccaria noted



Battery of Leyden Jars.

that these contractions were more marked than those arising as the result of other stimuli, such as pricking, or pinching the muscle.

About the middle of the eighteenth century medical electricity, for a time at least, enjoyed such advantages as may accrue from royal and other distinguished patronage. Not only royal physicians, but dukes, cardinals, and governors were all busy investigating reports of cures by the new therapeutic agent. Some cases, in which these aristocratic amateurs are called in as witnesses to the accuracy of the medical reports, form quaint reading and are thoroughly characteristic of the literary tendencies of the eighteenth century. One eminent physician cites the Duc de Richelieu as a witness of his veracity; another is not satisfied till he has quoted the

approval of Cardinal des Lances, a third invokes Cardinal Doria, while the Italian physician, Bianchini, in a letter to the Abbé Nollet, congratulates the Frenchman on being the subject of a great king who has at heart the welfare of science. The "great king" was Louis XV, who thus appears in a new *rôle* as a patron of anything but women, wine and hunting.

Beccaria.

Many will be surprised to hear that the French revolutionary, Marat, was a practitioner of electrotherapy. This extraordinary individual, who held among other medical qualifications the degree of M.D., St. Andrews, resided and practised in London for a time. During his stay he seems to have been well received in the best scientific circles, and was the author of several treatises upon medical and physical subjects; among

his works is one upon the employment of electricity in medicine. Marat subsequently returned to France and became physician to the bodyguard of the Comte d'Artois. His career subsequently to the year 1789 is only too well known, and, as Mr. Wallis says, in his paper on Marat,* "It would appear that Marat had two personalities: (1) The one that of a scientist and philosopher, which died in 1789, the year of the fall of the Bastille; (2) the other, that of a fanatical journalist, pamphleteer, and demagogue." According to the latest researches the career of Marat in England would appear to have been a strictly honourable one, and his scientific works seem to have commanded a respect to which they were fully entitled. In some of the earlier English accounts of Marat he was confounded with another, of the same or similar name, and who obtained a certain degree of notoriety from his inability to discriminate nicely between *meum* and *tuum*. The name of Jean Paul Marat has a sufficient load of infamy to bear without the additional burden of larceny.

The first London Hospital to invest in an electrical apparatus seems to have been the Middlesex (1767), and ten years later one was installed at St. Bartholomew's. About the same time John Birch, surgeon to St. Thomas's, was treating joint diseases and certain female disorders electrically at his hospital. Some of his writings attained quite a wide celebrity and were translated into various foreign languages.

Sir William Church, in the *St. Bartholomew's Hospital Reports* (Vol. XXII), gives some interesting details about the electrical machine, and mentions that in the year 1818, "The electrical machine—whether the original one purchased in 1777 or not, I know not—being out of order, was placed under the care of the apothecary, who was directed to employ Mr. Blunt, of Cornhill, when it needed repair." Whether Mr. Blunt declined, or was unable to repair the machine, does not appear, but the following year Mr. Latchford's report is entered in the minutes: "That the electrical machine at present in use was quite unfit to be repaired. It was proposed by him to make a new machine upon the modern principle, with a plate two feet in diameter, and all the apparatus and case complete to the satisfaction of the medical officers, and afterwards to keep the whole in good and constant repair for a sum not exceeding £17 18s., and that the machine be afterwards placed under the care of Mr. Latchford, but not to be taken out of the hospital, and

* Proc. Roy. Soc. Med., Vol. IX, 1916.

that Mr. Latchford will attend and electrify all the patients denoted by the medical officers to undergo the operation upon the following terms: if the operations within the hospital do not exceed thirty, at 2s. each, and if above that number, 1s. each. Resolved that the above conditions are approved of, and that the same be carried into effect without delay."

In the *History of Electricity*, Priestley refers to the fact that "electricity is now become a considerable article in the materia medica." The closing years of the eighteenth century

Galvani.

witnessed discoveries which were ultimately to revolutionise not only electrotherapy, but the science of electricity itself.

In 1791, Galvani, Professor of Anatomy at Bologna, noticed that the limbs of a freshly killed frog, when placed close to the prime conductor of an electrical machine, were thrown into violent convulsions. Further investigations showed that the leg of the frog, with its attached nerve, formed a delicate indicator for the presence of electricity, more delicate, indeed, than the Bennet's gold-leaf electroscope, which was at that time the most sensitive piece of apparatus known for the purpose.

Desiring to make some observations upon atmospheric electricity, Galvani made use of his newly found indicator, and suspended a number of such prepared frog legs, with their attached nerves, from an iron railing by means of metal hooks. He was surprised to find that marked contractions occurred, even when there was no evidence of any abnormal electrical atmospheric condition. Further investigations showed that the source of stimulation lay, not in the atmospheric electricity, but in the junction of two dissimilar metals suitably disposed as regards the nerve attached to the frog's leg: a more extended series of researches upon similar lines led Galvani to the conclusion that the most powerful contractions were excited by a combination of zinc and silver.* Galvani himself was led to an erroneous interpretation as to the result of his experiments, since he regarded the animal body as the source of the electricity, and conceived that the metals only served to discharge it, in the same way as a Leyden Jar is discharged.

The publication of these experiments of course set a number of observers to work upon similar lines. Fowler, in 1793, published his *Essay on Animal Electricity*, which contains many ingenious observations, though here again the observer was led to erroneous deductions; he recognised the necessity for the employment of two dissimilar metals, and described the sensation of light when such a metallic couple is suitably applied to the eyeball, but he could not bring himself to the conclusion that electricity was at the root of the matter. Some years previously a German observer, Sulzer, noticed that when two dissimilar metals were placed upon the tongue and themselves placed in contact, that a peculiar sensation of taste resulted; Sulzer attributed the sensation to a species of vibration set up in the metals and communicated to the tongue. About the same time Professor Robison performed a series of experiments upon the effects of metallic

* It is sometimes said that Galvani's experiment was anticipated by Swammerdam in an experiment which he performed before the Grand Duke of Tuscany, in 1668. Admittedly the three essentials of such an experiment, copper, silver and frog's leg, were present, but Dr. Althaus came to the conclusion that the contractions obtained were due to mechanical and not to electrical stimulation of the nerve. This claim for Swammerdam was first made by Duméril, in 1840, and was repeated by Matteucci and Golding Bird.

couples upon the senses of sight and taste, making special note of the effect of applying the tongue to the edges of a number of superimposed discs of silver and zinc.

The true explanation of these various phenomena was given by Volta, of Pavia, and was communicated by him to the Royal Society in 1793. He emphasised the necessity for a pair of dissimilar metals, and regarded the neuro-muscular manifestations as due to electricity produced by their contact. In 1799 Fabroni, of Florence, made some observations upon certain chemical phenomena and noted their connection with electrical or—as they were then called—galvanic influences. Thus, when certain metals were placed in contact in the presence of moist air, he found that oxidation occurred more rapidly than when they were separated, and drew attention to the instances of copper roofs when soldered with another metal, and to the copper sheathing of ships' bottoms when fastened with iron nails.

From the foregoing facts it will be seen that events were rapidly shaping themselves in preparation for the discovery of some form of electric cell whose energy was derived from chemical action.

In the year 1800, exactly two hundred years after the publication of Gilbert's masterpiece, Volta announced his discovery of the piece of apparatus which bears his name—the Voltaic Pile.

We have seen that Volta considered that two dissimilar metals placed in contact were capable, under suitable conditions, of producing electricity; he next conceived the idea of using a number of such metallic couples, and so producing a cumulative effect. The first apparatus constructed for this purpose consisted of a pile of silver coins and zinc discs, each pair being separated from its neighbours by a piece of card soaked in water; on simultaneously touching the two ends of the pile a distinct shock was experienced. Volta soon followed the construction of the Pile by the experiment known as the "Couronne de tasses," in which a number of small glasses were filled with some saline solution, and placed side by side; a number of pairs of strips of zinc and copper, or zinc and silver, were joined together by wires, and placed

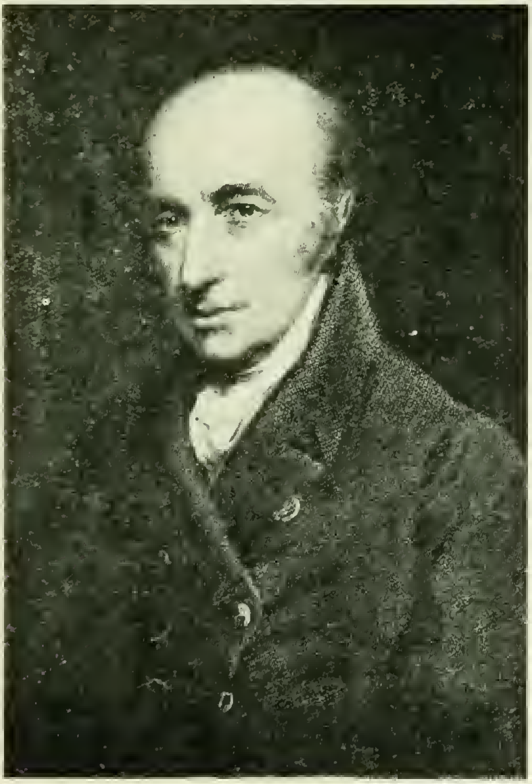
in the glasses in such a way that the zinc of one couple was in one glass, while the corresponding copper dipped into its neighbour. A number of these zinc-copper combinations being arranged as described, a system was produced which possessed properties identical with those of the Voltaic Pile.

Volta's own experiments with his primitive electric battery were exclusively confined to the animal body ; but as soon as

Volta.

his work was published a number of other investigators interested themselves in the new phenomena. Volta himself had concluded that since his pile was capable of giving a shock, it was a source of electricity. Nicholson and Carlisle not only incontestably proved the presence of electricity, but demonstrated the different electrical conditions of the two ends of the pile. About the same time (1803), Cruikshank modified the "*Couronne de tasses*" by placing the pairs of

plates in a trough and suitably connecting them. Sir Humphrey Davy demonstrated that pure water was useless as the liquid part of the system, as was also pure sulphuric acid—observations which have only received their full explanation in our own time, when it is known that the essential



Wm. Wollaston.

character of the solution employed is that it contains a suitable dissociated electrolyte.

The chemical side of the question was investigated by Wollaston and others; but in spite of accumulating evidence as to the importance of chemical changes, Volta persisted in his opinion that the sole source of the electricity lay in the simple contact of two dissimilar metals, and that the fluid merely served to convey electricity from one pair of plates to another.

Indeed, Volta himself does not seem to have participated in any of the discoveries that were made by means of his apparatus; he apparently occupied himself exclusively in experimental work, which he regarded as upholding his hypothesis of its mode of action.

Animal experiments, apart from Galvani's original experiment, had been performed upon invertebrate animals as early as 1793, by Fowler, who placed worms and other small creatures in contact with metallic couples, and recorded various forms of response to the stimulus. Experiments upon warm-blooded animals were of later development. Creve, of Wurzburg, produced contractions in a freshly amputated human leg; Vassali-Eandi, with his co-workers, Giulio and Rossi, carried out a series of experiments upon decapitated criminals at Turin. In this latter case attention was specially directed to the heart and other involuntary muscles, especially those of the stomach and intestine. Volta had asserted that the involuntary muscles were unaffected by his apparatus, a position which was controverted by Fowler. The conclusions of the Italian observers supported Fowler in maintaining that the involuntary muscles were affected.

In 1803, Aldini, Professor of Natural Philosophy at Bologna, published a treatise on "Galvanism"; among other experiments recorded therein was one in which he applied the terminals of a powerful battery to the body of a criminal hanged at Newgate, and recorded extraordinary convulsions and facial contortions as a consequence of the stimulation.

About the same time (1803) the therapeutic effects of galvanic electricity began to have a considerable trial, especially in such types of case as had been found to derive benefit from frictional electricity. As is usual with new remedies, grossly exaggerated accounts of its beneficial effects were circulated, with the inevitable result of bringing it into disrepute. It had been vaunted almost as a specific in "different nervous disorders, in paralytic affections, in deafness, in some kinds of blindness, in the recovery of the suffocated and drowned, and even in hydrophobia and insanity." *

* Bostock: "An Account of the History and Present State of Galvanism." London: 1818.

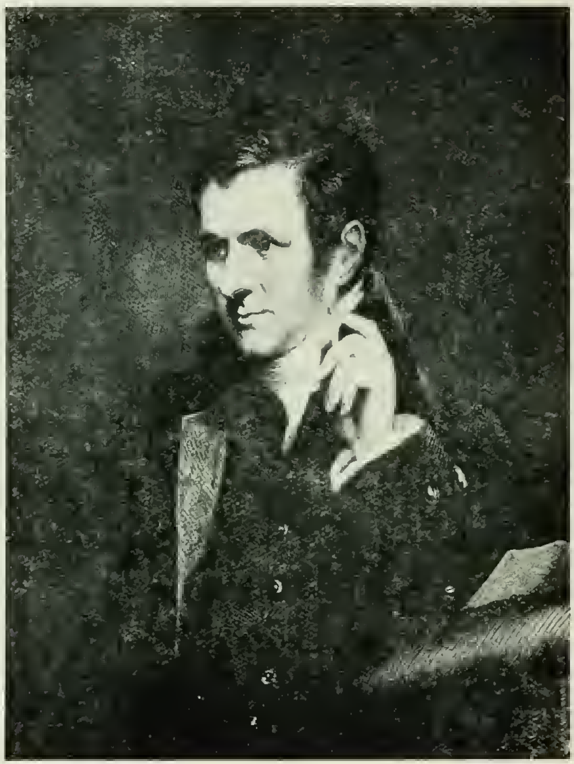
From about 1803, until after the discovery of electromagnetic induction by Faraday in 1831, the use of electricity as a therapeutic agent largely fell into disrepute. The reason of this is not far to seek. Exaggerated statements of its beneficial effects, such as those of Mauduyt, published by royal command at Paris in 1779, could not fail to be provocative of disappointment. Quacks, two of whom we shall notice in more detail shortly, were also largely responsible. The experiments of Aldini and others, though directed to a humane and useful end—the resuscitation of persons apparently drowned—found their way into the public press, with the inevitable result of producing a cataract of nonsense, in the noise of which the voice of real workers was unheard. Added to these circumstances was the fact that electricity was prescribed in all sorts and conditions of cases, which presented no indication for its use beyond the fact that they were intractable to ordinary therapeutic measures. So late as 1841, Golding-Bird wrote that, "on the occurrence of cases which refuse to yield to any ordinary remedy, the mandate, 'Let them be electrified,' has been often issued; too frequently, rather with a vague hope of obtaining relief from an extraordinary remedy than from any well-defined view of its real influence."

The early forms of voltaic battery were ineffective from their tendency to rapid polarisation, and it was necessary for more pure scientific work to be done before the use of electricity as a remedial agent could be put upon anything like a rational basis.

But even with primitive apparatus important discoveries were made soon after the discovery of the voltaic cell. In 1800 Nicholson and Carlisle produced the electrolysis of water, and in 1807 Davy succeeded in liberating sodium and potassium from their fused hydrates by the same means. The batteries in use were, however, still of the same simple type as before, and as Becquerel wrote (in 1834), "En 1820, la science électrique se trouvait dans un état stationnaire." However, in 1819, Oersted, Professor at Copenhagen, published his account of the action of the electric current upon the magnetic needle; a discovery which, according to Becquerel, did not

reach Paris until July, 1820. This, and the discovery of the "galvanic multiplier" by Schweiger about a year later, made the galvanometer possible, while Ohm formulated the law which bears his name in 1827.

It may be noted that the application of the current from an electric battery was early known as "galvanisation," instead

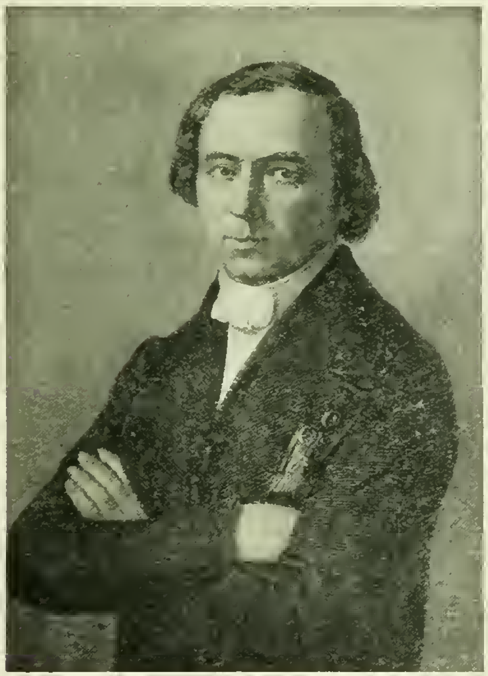


Sir Humphry Davy.

of (what would historically have been more correct) "voltaisation."

In view of the comparatively frequent occurrence of vesical calculus, and the difficulties of operation in pre-anæsthetic and pre-antiseptic days, it is not surprising that electrical treatment by the voltaic pile was early suggested. The first suggestions seem to have been those of Bouvier de Mortier in 1801, of Morgiardini and Lando in 1803, and of Gruithuisen

in 1813. In 1823, Prévost and Dumas performed experiments upon human calculi placed in water, and afterwards upon similar bodies introduced into the bladder of a living bitch. In the latter case a "fusible" calculus was introduced by means of a sound, and the electrodes were so adjusted that they touched it on opposite sides. Water was injected into

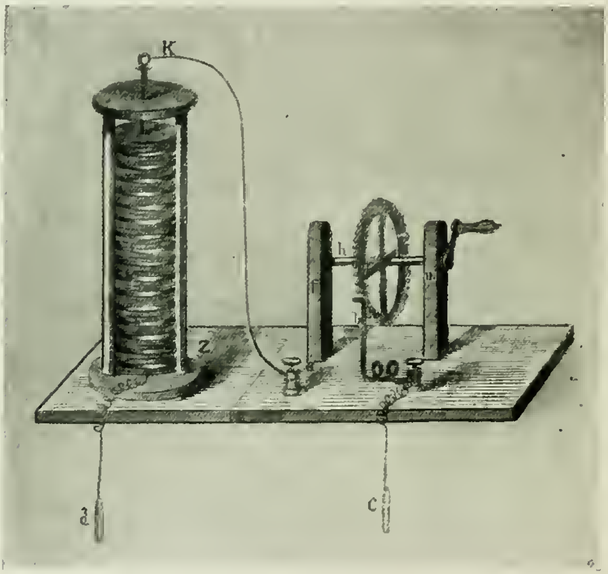


Dumas.

the bladder and the current from a voltaic pile of 120 pairs allowed to pass for an hour. At the end of that time the stone was withdrawn and showed signs of disintegration. This procedure was repeated for an hour morning and evening for six days, and at the end of that time the calculus was so friable that the operation could not be repeated. A few days afterwards the animal was killed, the bladder examined and found not to have been injured by the operation. Dr. Althaus, in recording the experiment, queries there having been no injury to the bladder, and remarks that "No human being could

possibly undergo what this poor bitch underwent without being killed by the inflammation which must necessarily follow such a proceeding."

Subsequent experiments on the solution of calculi *in vitro* were made by Bonnet, of Lyons, in 1835. Instead of employing water he immersed the stone in a solution of potassium nitrate, the idea being that the alkali liberated by the electrolysis of the salt would dissolve uric acid and urates,



Voltaic pile, fitted with hand-worked interrupter.

while the acid liberated at the other pole would dissolve phosphates. Calcium oxalate calculi were, according to this observer, not affected.

The experiments were repeated in 1853 by Bence Jones, who confirmed Bonnet's findings, with the exception that he found a slight solution of oxalate calculi to take place.

In 1841 Melicher, of Vienna, claimed to have dissolved calculi in the human bladder by galvanism, "but as he has not described the instruments used, nor given his cases in full detail, his statements are devoid of value." (Althaus.)

To complete the story of attempts to destroy calculi *in situ* by means of electricity, we may briefly refer to a small pamphlet of sixteen pages, by Dr. Robinson, of London, and published in 1855. It is entitled *On Electrolithotrity, or Application of the Electrical Discharge to the Disintegration of Stone in the Bladder.* The same author had previously described his method in a paper read before the Royal Society, in 1854, which bore for its title, *On the Disintegration of Urinary Calculi by the Lateral Disruptive Force of Electrical Discharge.* The pamphlet had a review in the *Lancet* of 1855, from which the following description is taken. Two insulated wires, uncovered at the free extremity where they are separated from each other by a distance of a tenth of an inch, are introduced into the bladder through an elastic catheter, and the free ends placed against the stone. The near ends of the wires are then to be connected to the two coatings of a Leyden Jar of large size in the usual manner. Dr. Robinson hoped that thereby the stone would be fractured by the force of the discharge. Fortunately he did not try the experiment on any living being, human or otherwise, but contented himself with experimenting on calculi placed in water contained in bladders or earthenware vessels. He records that he frequently cracked stones in this way, but that the earthenware vessels were often broken as well. Here the author leaves the matter in the hands of his professional brethren in the hope that they will give it a fair trial. The *Lancet* says, "In fine, for our limits preclude any extended notice of this subject . . . we think that lithotrity executed with a fair amount of dexterity is a far more safe, successful and agreeable mode of extracting the calculus, in a large majority of cases, than by any appeal to Jupiter Tonans for the use of his imperial bolts."

Here, perhaps, we may be permitted to digress a little to consider two rather celebrated quacks who took electrotherapy for the sphere of their activities. Of these, the first in order of time, and equally so in impudence, was the notorious James Graham (1745-1794). He wrote M.D. after his name and claimed to be a graduate of Edinburgh University, although the University modestly disclaims any pretension to be his

alma mater. Graham was a voluminous writer—and speaker; the Catalogue in the British Museum reading room devotes nearly a whole column to his effusions. Like most quacks he did a vast amount of travelling about, but his presence in various towns does not seem always to have been welcome to the local authorities, to whom he accordingly refers in no complimentary terms. At Newcastle, for instance, the mayor very properly objected to Graham delivering his celebrated lecture, and was accordingly treated, not only to some scurrilous abuse, but to no less than three visits in one day from the quack himself. The first visit was made at 6 a.m., and the second at 8 a.m., and on both occasions the mayor was reported to be in bed, much to Graham's indignation. A third visit at 10 a.m. procured an interview, but apparently his reception was not as cordial as he desired.

Graham styled himself "President of the Council of Health," and started the "Temple of Health" in London, where he delivered lectures and promised immediate pregnancy to the barren by the use of his "Celestial Bed." I have given a photograph of the title-page of his lecture, which was sold for the modest sum of half-a-crown. On the inside of the title-page is another page of advertisements, in which he informs the world in general that his electrical apparatus cost £12,000, and mentions that he had received unsolicited testimonials from the Duchess of Devonshire, Lady Spencer, Lady Clermont, Earl Spencer, and the Prince of Hesse Cassel. Among the published works advertised in the same place is a pamphlet of "Private Medical Advice," the normal price of which was one guinea, but which, owing to the impending departure of its author from London, might be had for half that sum. As this precious document consists of only eight pages, he ought to have made a good thing out of its sale. The lecture he boasts of having delivered over five hundred times, and explains that the printed text differs somewhat from the *viva-voce* performance because of the large numbers of ladies and clergymen who attended his public readings! But hearing the expurgated production was not sufficient; in a note to the printed version he says: "My gentle and intelligent reader! pray read the following lecture very slowly and deliberately,

A LECTURE

ON THE

GENERATION, INCREASE, AND IMPROVEMENT

OF THE

HUMAN SPECIES!

INTERSPERSED WITH

PRECEPTS FOR THE PRESERVATION AND EXALTATION OF

PERSONAL BEAUTY AND LOVELINESS;

AND

For prolonging HUMAN LIFE, Healthily and Happily,

To the very longest possible PERIOD of HUMAN EXISTENCE!

This curious, most eccentric, most important, and most cordially concentric LECTURE, is begun with enumerating the safest and most efficacious WAYS and MEANS of producing

A Numerous, a Healthy, a Beautiful, and a Virtuous OFFSPRING;

And is closed with a glowing, brilliant, and supremely delightful Description of the STRUCTURE, and most irresistibly GENIAL INFLUENCES of the CELEBRATED

CELESTIAL BED!!!

THE WHOLE ILLUSTRATED AND EMBELLISHED WITH

A just and spirited Review of the Candour of NEWS-PAPER DOERS; of the present Professors and Administrations of POLITICS, LAW, PHYSIC, and DIVINITY;

AND WITH

A Naked Exhibition of ASSES, stripped of their ERMINE,

NAMELY,

OF COUNTRY JUST-ASSES, MARES, ALDERWOMEN, and WHIPPERS-IN;

By JAMES GRAHAM, M.D.

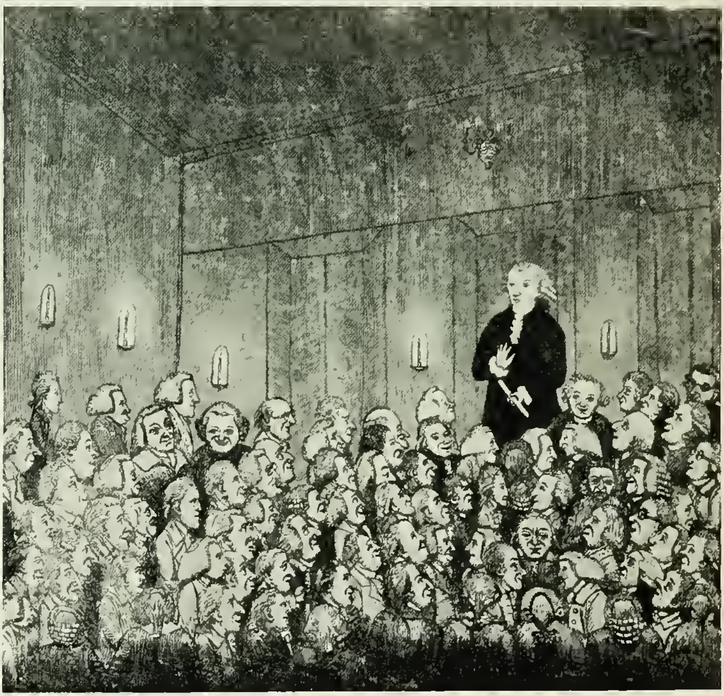
President of the COUNCIL of HEALTH!—Sole Proprietor, and principal Director of the TEMPLE of HEALTH! in PALL-MALL, near the KING'S-PALACE.

LONDON PRINTED,

And Sold at the Temple of Health; at the Pamphlet Shop, under the Front Piazza of the Royal Exchange; and at Mr. Rieu's Pamphlet-Shop, opposite Anderton's Coffee-House, No. 55, Fleet-Street.—Price *Two Shillings* and *Six-Pence*.

Title-page of Graham's Lecture. (Reduced—the original is 4to.)

a line in a minute! and read the whole lecture over once every month so long as you live." What the spoken discourse was like I have not been able to ascertain, but the written one is about as nauseous a collection of obscenity and cant as could well be devised. As regards the latter characteristic, Graham had great ideas of his powers as a preacher, and several of his sermons are printed. On one occasion, when his activities



Graham Lecturing.
(Kay's *Edinburgh Portraits.*)

had secured him a temporary residence in the Tolbooth of Edinburgh, he treated his fellow prisoners to a specimen of this style of oratory. To crown all, the (printed) lecture contains an advertisement of his "anti-venereal essence," "Imperial pills," and other similar nostrums, all obtainable at the Temple of Health, at prices varying from half-a-crown to a guinea. The "Celestial Bed" was a gorgeous structure, supported on forty pillars of brilliant glass, fitted with magnets and various "electrical" devices, and also termed by its

proprietor the medico-magnetico-musico-electrical bed. Towards the end of his days he fell upon evil times and was constrained to advocate earth or mud-baths. Beer, tobacco, and woollen clothes all come in for his adverse criticism, expressed with the same moderation as his views on most people and things with which he did not agree (the people, by the way, including bishops, physicians, justices of the peace, and electrical quacks), and whom he belabours in a manner which is reminiscent of Gideon Harvey's diatribes against the College of Physicians and the Apothecaries. A modest request at the end of the lecture is for some benevolently minded person to leave him £400 per annum for life, in order that he might prosecute his researches. It is said that Amy Lyon, better known afterwards as Lady Hamilton, officiated in his "Temple" as the goddess of health.

Another notable quack was Elisha Perkins, who invented "Metallic Tractors," for which he took out an American patent in 1796, his son Benjamin following with an English patent in 1798. These were shaped something like the limbs of a pair of compasses, with the points of different metals, and were employed by being stroked over the surface of the skin; the idea of course being derived from Galvani's discovery of the action of metallic couples in producing muscular contraction. They had an enormous vogue in England and in Denmark, and succeeded in deceiving a large number of people of respectable position with regard to their efficiency.

Needless to say, the caricaturists of the time made free with the tractors; a little volume of doggerel verses, called *Terrible Tractoration*, was directed against them, and also apparently against Aldini and his experiments on executed criminals, and against Sir Humphrey Davy's experiments with nitrous oxide gas. I say "apparently," because although both Aldini and Davy are satirised, the author's preface explains that they are "introduced merely for the purpose of giving them publicity and thus promoting the interest of science."*

* The title, as given on the title-page, is "Terrible Tractoration!! a poetical petition against Galvanising Trumpery and the Perkinistic Institution . . . most respectfully addressed to the Royal College of Physicians, by Christopher Caustic, M.D., LL.D., ASS., Fellow of the Royal College of Physicians, Aberdeen, and honorary member of no less than nineteen very learned societies. . . . 1803." A MS. note in the copy belonging to the Royal Society of Medicine states that the book was written by Thomas Greer Fassenden.

According to the same preface the work must have had an extraordinary popularity, since the first edition was exhausted in a couple of months. The following is a fair specimen of the verses, which occupy somewhere about half of a hundred and eighty-six pages, the other half being occupied with more or less satirical footnotes ; it is taken from page 60, *et seq*, of the second edition:—

Behold what ought to raise your spleen high
Perkins supported by Aldini,
It must have been most sad, foul weather
From Italy, to blow him hither.

My wrath, indeed, is now so keen, I
Ev'n wish, for sake of that Aldini,
This *ink* were *poison* for the wizard
This *pen* a *dagger* in his gizzard !

For he ('tis told in public papers),
Can make dead people cut droll capers,
And shuffling off death's iron trammels,
To kick and hop like dancing camels.

To raise a dead dog he was able,
Though laid in quarters on a table,
And led him, yelping, round the town,
With two legs up, and two legs down.

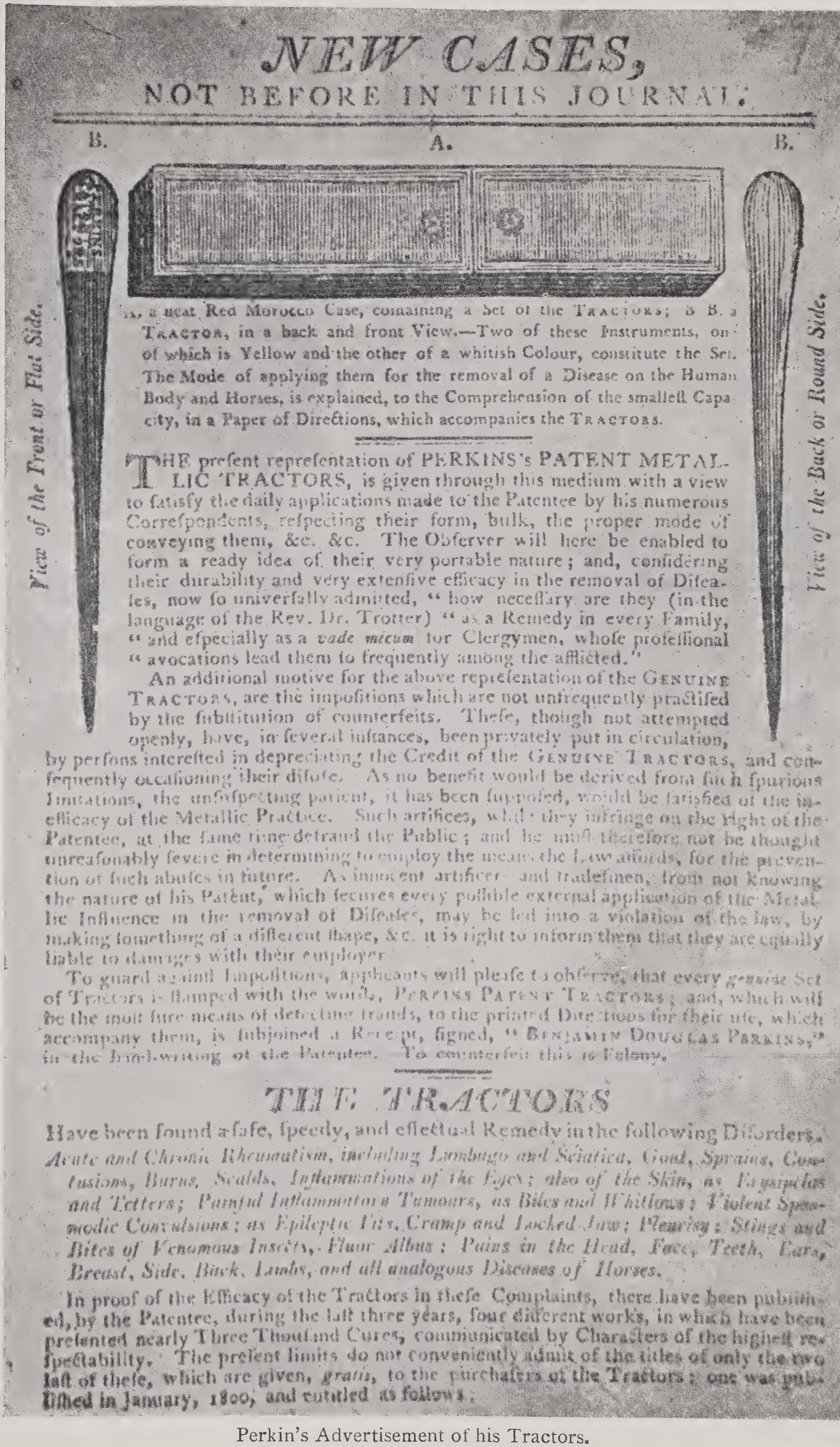
And in the presence of a posse
Of our Great Men and ANDREOSSI,
He show'd *black art*, of worse description,
Than e'er did conjuring Egyptian.

He cut a bullock's head, I ween,
Sheer off, as if by guillotine ;
Then (Satan aiding the adventure)
He made it *bellow* like a Stentor !

And this most comical magician
Will soon, in public exhibition,
Perform a feat he's often boasted,
And animate a dead pig—*roasted*.

With powers of these Metallic Tractors,
He can revive dead malefactors ;
And is re-animating daily,
Rogues that were hung *once*, at Old Bailey !

The references of course are to Aldini's experiments with reference to the possible use of electricity in restoring persons



NEW CASES,

NOT BEFORE IN THIS JOURNAL.

A, a neat Red Morocco Caſe, containing a Set of the TRACTORS; B B, a TRACTOR, in a back and front View.—Two of theſe Inſtruments, one of which is Yellow and the other of a whitiſh Colour, conſtitute the Set. The Mode of applying them for the removal of a Diſeaſe on the Human Body and Horſes, is explained, to the Comprehenſion of the ſmalleſt Capacity, in a Paper of Directions, which accompanies the TRACTORS.

THE preſent repreſentation of PERKINS's PATENT METALLIC TRACTORS, is given through this medium with a view to ſatiſfy the daily applications made to the Patentee by his numerous Correſpondents, reſpecting their form, bulk, the proper mode of conveying them, &c. &c. The Obſerver will here be enabled to form a ready idea of their very portable nature; and, conſidering their durability and very extenſive efficacy in the removal of Diſeaſes, now ſo univerſally admitted, "how neceſſary are they (in the language of the Rev. Dr. Trotter) "as a Remedy in every Family, "and eſpecially as a *vade mecum* for Clergymen, whoſe profeſſional "avocations lead them ſo frequently among the afflicted."

An additional motive for the above repreſentation of the GENUINE TRACTORS, are the impoſitions which are not unfrequently practiſed by the ſubſtitution of counterfeits. Theſe, though not attempted openly, have, in ſeveral inſtances, been privately put in circulation, by perſons intereſted in depreciating the Credit of the GENUINE TRACTORS, and conſequently occaſioning their diſuſe. As no benefit would be derived from ſuch ſpurious Imitations, the unſuſpecting patient, it has been ſuppoſed, would be ſatisfied of the inefficacy of the Metallic Practice. Such artifices, while they infringe on the right of the Patentee, at the ſame time defraud the Public; and he muſt therefore not be thought unreaſonably ſevere in determining to employ the means the Law affords, for the prevention of ſuch abuſes in future. As innocent artificers and tradeſmen, from not knowing the nature of his Patent, which ſecures every poſſible external application of the Metallic Influence in the removal of Diſeaſes, may be led into a violation of the law, by making ſomething of a different ſhape, &c. it is right to inform them that they are equally liable to damages with their employer.

To guard againſt Impoſitions, applicants will pleaſe to obſerve, that every *genuine* Set of Tractors is ſtamped with the words, PERKINS PATENT TRACTORS; and, which will be the moſt ſure means of detecting frauds, to the printed Directions for their uſe, which accompany them, is ſubjoined a Receipt, ſigned, "BENJAMIN DOUGLAS PERKINS," in the hand-writing of the Patentee. To counterfeit this is Felony.

THE TRACTORS

Have been found a ſafe, ſpeedy, and effectual Remedy in the following Diſorders.

Acute and Chronic Rheumatiſm, including Lumbago and Sciatica, Gout, Sprains, Contuſions, Burns, Scalds, Inflammations of the Eyes; alſo of the Skin, as Eryſipelas and Tetters; Painful Inflammatory Tumours, as Biles and Whitlows; Violent Spaſmodic Convulsions; as Epileptic Fits, Cramp and Locked Jaw; Pleuriſy; Stings and Bites of Venomous Inſects, Fluor Albus: Pains in the Head, Face, Teeth, Ears, Breast, Side, Back, Limbs, and all analogous Diseases of Horſes.

In proof of the Efficacy of the Tractors in theſe Complaints, there have been publiſhed, by the Patentee, during the laſt three years, four different works, in which have been preſented nearly Three Thouſand Cures, communicated by Characters of the higheſt reſpectability. The preſent limits do not conveniently admit of the titles of only the two laſt of theſe, which are given, *gratis*, to the purchaſers of the Tractors; one was publiſhed in January, 1800, and entitled as follows;

Perkin's Advertisement of his Tractors.

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Metallic Tractors. (Reproduced from a caricature in the Wellcome Historical Medical Museum.)

who had been partially drowned or strangled, a subject upon which he wrote a tract, dedicated to the Governors of the Royal Humane Society, in 1819. His apparatus consisted of a "pile" of 120 plates of copper and zinc, separated by pieces of cloth and immersed in a dilute solution of ammonium chloride. He suggests also mechanical means for regulating and recording the number of shocks given, such, for instance, as by a lever worked by hand, which was attached to a recording dial, or by a pendulum so arranged that, "supposing the vibrations to take place every second, the patient may experience in half an hour 1,800 galvanic shocks, recorded on a dial." The author of the "Terrible Tractoration" gives a couple of extracts from the *Morning Post* in his footnotes, which may be of sufficient interest to warrant their inclusion here. The first is from the *Morning Post* of February 16th, 1803, and is as follows :—

"Some curious Galvanic experiments were made on Friday last, by Professor Aldini, in Doctor Pearson's Lecture Room. They were instituted in the presence of his Excellency the Ambassador of France, General Andreossi, Lord Pelham, the Duke of Roxburgh, Lord Castlereagh, Lord Hervey, the Hon. Mr. Upton, etc. The head of an ox, recently decapitated, exhibited astonishing effects; for the tongue, being drawn out by a hook fixed into it, on applying the exciters, in spite of the strength of the assistant, was retracted, so as to detach itself by tearing itself from the hook; at the same time a loud noise issued from the mouth, attended by violent contortions of the whole head and eyes."

The second extract given is from an earlier number of the same paper, dated January 22nd, 1803 :—

"The body of Forster, who was executed on Monday last, for murder, was conveyed to a house not far distant, where it was subjected to the *Galvanic* Process, by Professor Aldini, under the inspection of Mr. Keate, Mr. Carpue, and several other Professional Gentlemen. M. Aldini, who is the nephew of the discoverer of this most interesting science, shewed the eminent and superior powers of *Galvanism* to be far beyond any other stimulant in nature. On the first application of the process to the face, the jaw of the deceased criminal began to quiver, and the adjoining muscles were horribly contorted, and one eye was actually opened. In the subsequent parts of the process the *right hand was raised and* CLENCHED, and the legs and thighs were set in motion.

"It appeared to the uninformed part of the bystanders as if the wretched man was on the eve of being restored to life. This

however was impossible, as several of his friends, who were near the scaffold, had violently pulled his legs in order to put a more speedy termination to his sufferings."

Aldini * recommends the use of "galvanism" in order to prevent premature burial, and both from his writings and from references to him by others, the unfairness of associating him, even in jest, with such impostors as Perkins is manifest. To some extent he seems to have studied English in the school of Dr. Johnson, since he refers to a puppy used in one of his experiments as "a young quadruped of the canine species."

Frontispiece of *Terrible Tractoration.* London, 1803, 2nd Ed.

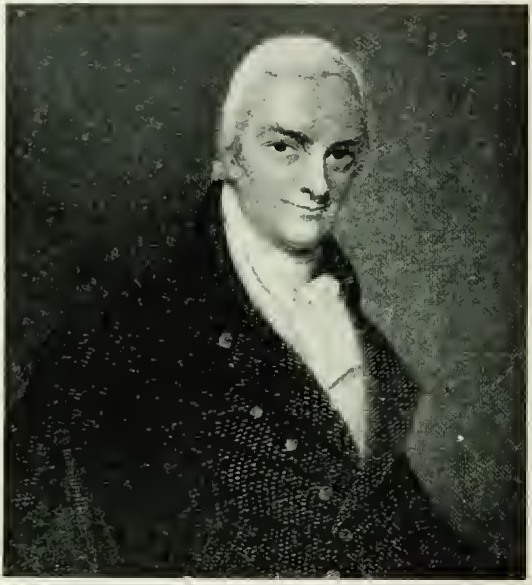
Haygarth of Bath, and Smith of Bristol, finally exploded the Tractor quackery by producing the same effects with wooden instruments.

About 1809, there was at least one "Electrical Institute" in London, namely, that of Lowndes, in St. Paul's Churchyard. It was under the advice of Buchan, the author of the once popular *Domestic Medicine*, that Lowndes came to London, and in the preface to the 1809 edition of the book is the following :—

"It (*i.e.* the book) is also, in order to render it still more valuable, enriched with some useful engravings, illustrative of

*Aldini was Galvani's nephew.

important subjects; one is a View of the splendid Electrical Machine of Mr. Lowndes, of St. Paul's Churchyard, the largest in this country, and the most successful yet employed in the cure of diseases. It has properly a place in this work, as, under Dr. Buchan's auspices, Mr. Lowndes first began his career of medical practice. Electricity, formerly applied at random, without attention to correct principle, has, in the hands of this gentleman, been brought to greater practical utility and certainty in the cure of diseases than before his time."

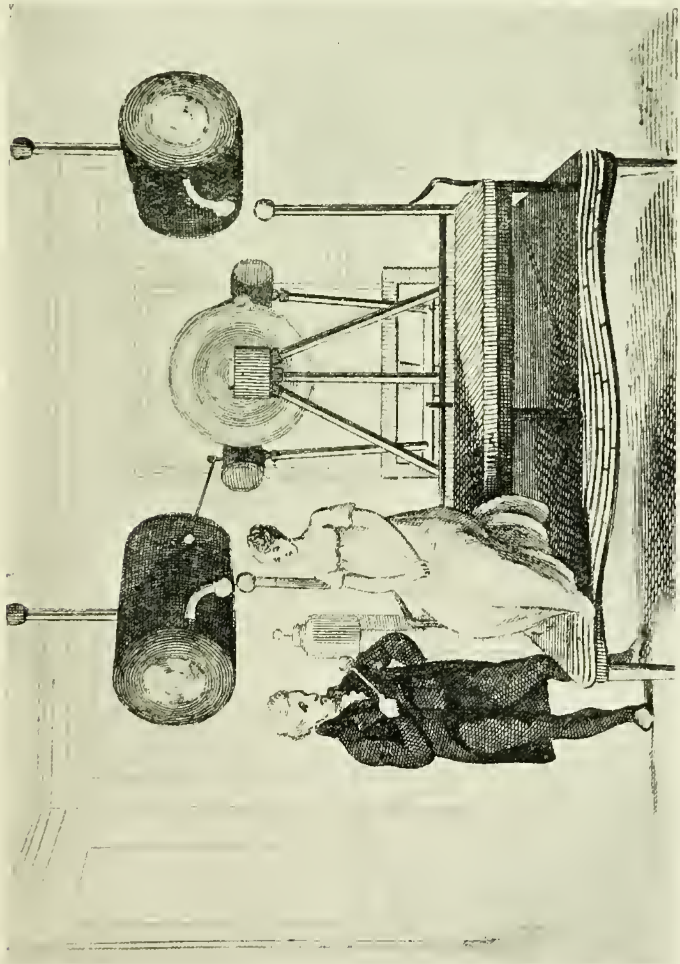


John Haygarth.

Whether Mr. Lowndes had a proprietary interest in the book, or the publishers of the book in Mr. Lowndes, is not stated, neither are we told if the man in the picture is Mr. Lowndes. If so, there would seem to be a strong family likeness to Punch, which is not lessened by the way he holds what looks like a big drum-stick, but is probably an apparatus for drawing sparks from his victims.

Experiments on executed criminals were fairly numerous at the beginning of the nineteenth century, and a French observer, Nysten, records his adventures in trying to obtain the remains of somebody who had been guillotined. The last trouble he had was with the keeper of the cemetery

whither the body was conveyed, this official protesting that anatomical dissections were against all law and precedent. However, Nysten eventually succeeded in carrying out his



Lowndes' "Grand electrical apparatus."

experiments in a newly dug grave, and in proving to his own satisfaction that the heart retains its power of response to electrical stimuli for a longer period than any other muscle of the body.

Several workers tried to rescue electricity as a remedial

agent from the condition of disrepute into which it had fallen, but generally speaking, ineffectually. Among these was Dr. Philip, of Worcester, who communicated a paper to the Royal Society in 1817, in which he recommended it as a treatment for spasmodic asthma. His battery consisted of from eight to sixteen plates, four inches square, immersed in a trough containing a mixture of one part hydrochloric acid in twenty parts of water. For electrodes, he took two thin metal plates, two or three inches in diameter; these were dipped in water, and one was applied to the back of the neck and the other to the epigastrium. The current was allowed to pass for varying periods until the patient said his breathing was easier; sometimes from fifteen to twenty minutes were required, but, as a general rule, the treatment was to give a daily sitting of ten minutes over a period of eight to ten days.

Golding-Bird's Electric Moxa.

A peculiar blending of the Old and the New was the "Electric moxa." The moxa, originally, consisted of a little mass of combustible material placed upon the body and ignited, so as to produce a burn at the site of application. Cotton wool or the pith of the sunflower was the basis of some of the old English forms, and it formed a prominent feature in Chinese and Japanese medicine. Usually several were employed at the same time. The aim was either simple counter-irritation or the production of a running sore, with the idea of relieving trouble in some other part of the body. Other gentle means of producing counter-irritation were the actual cautery (of hot iron) and the introduction of setons, the latter being strips of linen, horse hairs or such-like introduced beneath the skin, doubtless in pre-antiseptic days producing abundance of pus.

The electric moxa was, from the patient's point of view at any rate, decidedly preferable; Golding-Bird describes its uses and application as follows: "We are often anxious to produce a persistent discharge from some part of the body, in cases when an issue or seton, or discharge from the moxa or actual cautery would be desirable. Now the knife for the issue, and the ignited tinder or red-hot iron for the moxa, all have their

terrors for timid patients, and there is often the greatest unwillingness to induce patients to use such means. There are, therefore, considerable advantages in the use of a plan which, while it is perfectly competent to produce a copiously discharging sore, shall at the same time not excite the alarm of the most sensitive patient. As I believe this *electric moxa*, as I have termed it, is often of very great value, I may be excused giving more minute directions for forming it. Order two small blisters the size of a shilling to be applied to any part of the body, one a few inches below the other ; when the cuticle is thus raised by effused serum, snip it, and apply to the one from whence a permanent discharge is required a piece of zinc foil, and to the other a piece of silver, connect them by a copper wire and cover them by a common water dressing and

Golding-Bird's Electric Moxa.

oiled silk. If the zinc plate be raised in a few hours, the surface of the skin will look white, as if rubbed over with nitrate of silver. In forty-eight hours a decided eschar will appear, which (still keeping on the plates) will begin to separate at the edges in four or five days. The plates may then be removed, and the surface where the silver was applied will be found to be completely healed. During the whole of this process, if the patient complains of pain at all, it will always be referred to the silver plate, where in fact the blister is rapidly healing, and generally not the smallest complaint will be made of the zinc plate, where the slough is as rapidly forming." This little apparatus was not devised to act as a moxa originally, but was designed for a stimulant by local electrical action and employed in cases of, *e.g.*, hemiplegia. The formation of issues, whether by cautery, moxa, or seton, is of course now extinct, but, granting its utility, we must admit that Golding-Bird had found what must have been a very considerable alleviation of the "terrors for timid

patients," and that therefore the treatment was a decided advance on older methods.

Faraday.

The year 1831 marks a new era in the history of electricity, since it saw the discovery of electro-magnetic induction by Faraday, while an independent discovery of induced electric currents was made about the same time by the American physicist, Joseph Henry, to whom important later develop-

Michael Faraday.

ments on self- and mutual-induction of conducting circuits were also due, and who was the first to observe the oscillatory nature of the discharge from the Leyden Jar.

So early as 1825 Faraday devised experiments to ascertain whether voltaic electricity presented any phenomena either identical with, or analogous to, those of induction in static electricity. For this purpose he connected a wire with a galvanometer and stretched alongside it a second wire in which a current was flowing. He records the experiment as

yielding no deflection of the galvanometer needle. "A very little step in experimental research often separates failure from success. A reversal of operations, a change of some dimension, an alteration of some proportion, is often all that is needed to step from the region of failure into the field of discovery and achievement. In this case it may have been the apparently trivial one of starting the electric current in one wire *before* completing the circuit of the galvanometer" (Fleming). The experiment was tried again in 1828, once more with a negative result. On the 29th of August, 1831, he recorded as follows

Faraday's apparatus.
(Now in the Royal Institution.)

in his laboratory note book at the Royal Institution : "I have had an iron ring made (soft iron), iron round and $\frac{7}{8}$ in. thick, and ring 6 in. external diameter. Wound many coils of copper round one half of it, the coils being separated by twine and calico ; there were three lengths of wire, each about 24 ft. long, and they could be connected as one length or used as separate lengths. By trials with a trough, each was insulated from the other. We will call this side of the ring A. On the other side, but separated by an interval, was wound wire in two pieces, together amounting to about 60 ft. in length, the direction being as with the former coils. This side call B. Charged a battery of ten pairs of plates, 4 in. square. Made

the coil B side one coil, and connected its extremities by a copper wire passing to a distance and just over a magnetic needle (3 ft. from wire ring), then connected the ends of one of the pieces on A side with battery; immediately a sensible effect upon needle. It oscillated and settled at last in original position. On breaking connection of A side with battery, again a disturbance of the needle."

Thus, in its author's own words, the epoch-making discovery of electro-magnetic induction.

Again, on the 24th of September of the same year, an iron cylinder was wound round with a helix of insulated copper wire. The iron was then placed between the poles of bar magnets, the ends of the helix being connected with a galvanometer, when it was noticed that every time the ends of the iron cylinder were brought into contact with the magnets a deflecton of the galvanometer needle occurred.

An experiment made on the 1st of October, 1831, brings the induction coil another step nearer. Having prepared a battery of a hundred pairs of copper and zinc plates, four inches square (the exciting liquid being a mixture of sulphuric and nitric acids), Faraday took a copper wire 203 feet long and wound it on a wooden bobbin. Around the same bobbin, parallel to the first wire, but insulated from it, was wound a second similar wire, the ends of which were connected with the terminals of a galvanometer. On now connecting the first wire with the battery it was noticed that a small but sudden jerk of the galvanometer needle occurred; likewise, on breaking the circuit another momentary deflection of the needle took place, but in the opposite direction to its first movement.

At the same time as Faraday was prosecuting his researches in this country, Joseph Henry was independently obtaining similar results in the United States. He had already improved upon Sturgeon's original electro-magnet—a horse-shoe of iron with a single layer of wire wound round it—by substituting a bobbin of many layers of insulated wire with an iron core; and in 1829 or 1830 had constructed a large electro-magnet capable of sustaining a weight of six or seven hundred pounds.

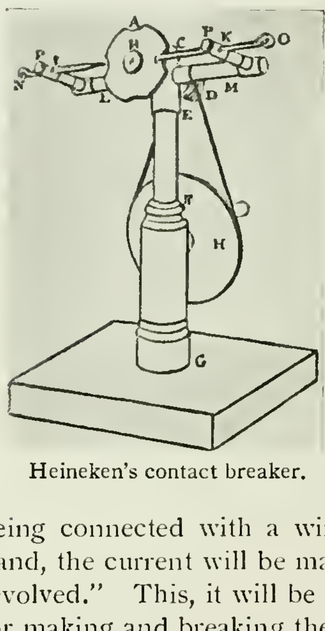
Here then was the germ of the induction coil, but it is obvious that in order to obtain a workable apparatus for the

application of induced currents some form of contact breaker must be employed between the battery and the primary coil. It will be remembered that Aldini suggested such a device when administering shocks directly from a battery of cells. Other forms were worked by hand and consisted of some form of cog and rachet arrangement. One form of apparatus used in connection with a voltaic pile we have already figured (see p. 39), while another designed by the Rev. N. S. Heineken, and

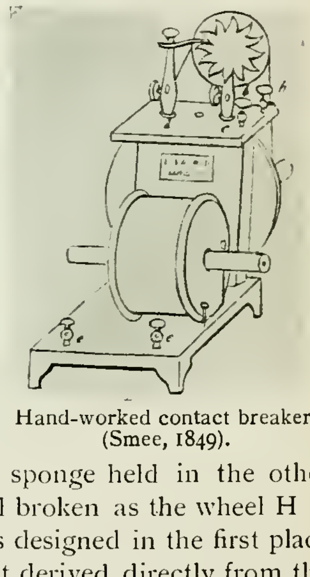
Joseph Henry.

illustrated here, was described in the *Philosophical Magazine* for 1837. The figure hardly needs description, but the following brief summary, taken from Heineken's paper, may be useful: "A is a thin wheel of copper having four or more circular indentations at equal distances in its circumference. It is fastened by a nut at B to a spindle which passes through the brass tube C and has at its other end a pulley D. The tube is insulated by the glass pillar EF fixed into the wooden support FG, and by this attached to the base. H a wheel, by turning which the pulley D and disc A revolve. IK two brass

arms attached by mountings to glass tubes at L and M, and by them insulated and fixed also to CE. Then two brass arms hold the copper wires NO by means of the screw PP. The wire N has its end formed into a slight spring ; so also has O. That at N touches the copper disc A only where the circumference is entire ; that at O always presses lightly on the face of the disc. The method of action is now fairly plain; a wire connected with one extremity, say O, terminates in a moist sponge, which is held in the hand, while the other, N, is connected to one pole of the battery, the other battery pole



Heineken's contact breaker.



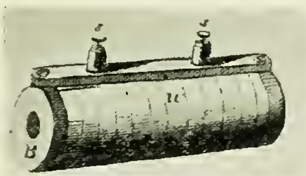
Hand-worked contact breaker (Smee, 1849).

being connected with a wire and sponge held in the other hand, the current will be made and broken as the wheel H is revolved." This, it will be seen, is designed in the first place for making and breaking the circuit derived directly from the battery. It obviously might also be used as a mechanical make and break when suitably connected between the battery and the primary of an induction coil.

These contact breakers, which were worked by an assistant, seem to have been in use as late as 1849, since Golding-Bird, of Guy's Hospital, says in his "Lectures," published in that year, "You may break contact with the battery, if you please, by means of a ratchet or cog-wheel, but this is often inconvenient, as it renders the services of an assistant necessary

On this account an automatic apparatus is always to be preferred." He then goes on to mention that he believes he was the first to devise a working automatic apparatus (in 1838), which he described in the *Philosophical Magazine*, but that now (*i.e.*, 1847)* he only employs an automatic apparatus made by "an ingenious optical instrument maker, Mr. Neeves, of Broad Street, Holborn."

Golding-Bird's original apparatus is partly shown in the accompanying sketch, taken from his article in the *Philosophical Magazine*, and it is certainly a little complicated. A and B are two blocks of hard wood mounted on a suitable base, each having two holes excavated in it for the purpose of holding



Small electro-magnet for surgical use. (Smee, *Electrobiology*, 1849.)

mercury. Each hole is connected with the corresponding one in the other block of wood by a thick copper wire DD[1]. In the centre of the base board is a wooden support, carrying an oscillating lever EF, made of a piece of soft iron wire, $\frac{1}{8}$ in. in diameter and 5 in. in length. It is supported between the cheeks cut in the upper part of the wooden support by milled-headed screws, so adjusted that it oscillates with a minimum amount of friction. Around the iron wire are wound two helices of insulated copper wire, in the same direction (from right to left), and in such a manner that the two ends of one helix may terminate in the copper points GH, while those of the other helix terminate in the points KL. Two small horse-shoe magnets (which are not shown in the figure) are then fixed on suitable supports, so that each is near one end of the lever EF, and in a plane just posterior to it, so that on depressing the end F of the lever it may be opposite one pole (say the south) of the one magnet, and consequently the other

* The *Lectures* were first delivered in 1847, though their publication in book form was in 1849.

end E will be opposite to the other pole of the second magnet. On elevating the end F the contrary will take place, and for this purpose the similar poles of the magnets must be in the same direction.

On connecting the cups of mercury in A or B with the two plates of a single voltaic battery, the bar EF will become a temporary magnet if the ends of either helix are allowed to dip in the mercury; if connection with the battery is properly made the ends or poles of the temporary magnet will be repelled by the poles of the permanent magnet to which they are opposed. The lever will consequently move and cause the immersion of the ends of the other helix in the other cups

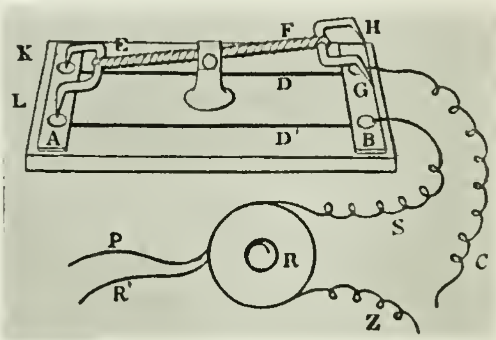
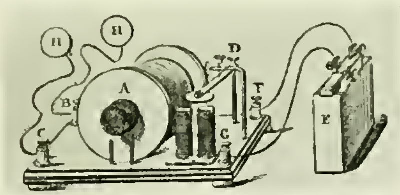


Diagram of Golding-Bird's contact breaker (1838).

of mercury. The process will be repeated so as to cause the lever to oscillate. About 300 oscillations per minute were obtained by this apparatus.

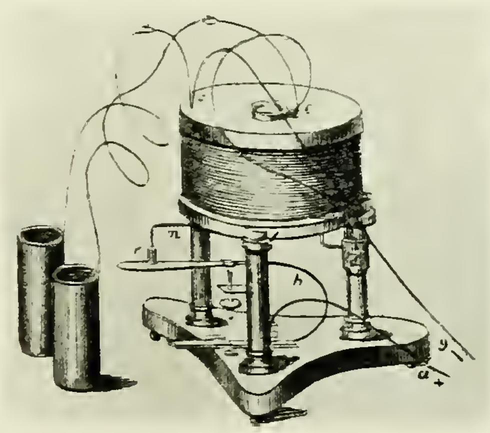
The modern make and break used in small coils is the well known Neef's hammer, invented by Dr. Neef, of Frankfurt. In connection with this name we may notice, in Golding-Bird's "Lectures," a drawing of a coil fitted with a hammer contact breaker which, from the wording, one would imagine was *invented* as well as *made* by Neeves, an instrument maker of London. As this point is interesting the author's own words may be quoted: "As we have seen that in all such contrivances (*i.e.*, induction coils) a small voltaic current furnishes the initial force, it is important to have this completely under command, and to be able to make and break contact with the

inducing apparatus with the utmost facility and rapidity. You may break contact with the battery, if you please, by means of a rachet or cog-wheel; but this is often inconvenient, as it renders the service of an assistant necessary. On this account an automatic apparatus is always to be preferred. I



Automatic contact breaker. Made by Neeves. (Golding-Bird, *Lectures*, 1849.)

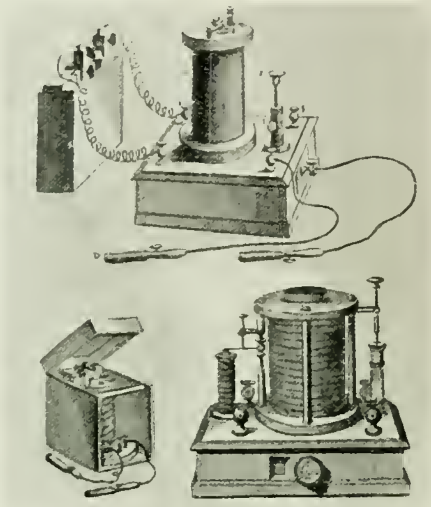
believe I proposed the first of these several years ago, in the *Annals of Philosophy*; but this as well as all others I have seen is much inferior to one constructed by a ingenious philosophical instrument maker, Mr. Neeves, of Broad Street,



Neef and Wagner's induction coil.

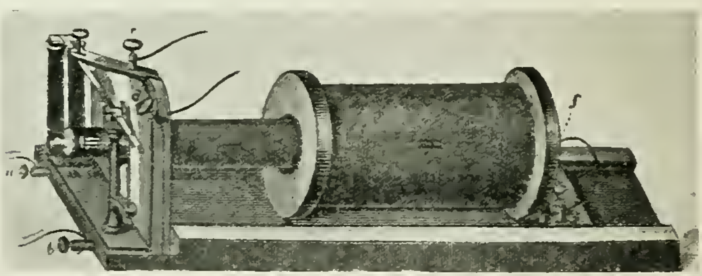
Holborn, and this is the only one I ever now employ." This piece of apparatus is illustrated in the accompanying photograph from Golding-Bird's book. What the true history of the case is I do not know, nor whether the names have become confused; it at any rate seems clear, from the above

that Golding-Bird regarded Neeves as the person to whom the apparatus owed its existence. Neef and Wagner worked with an induction coil of which we also give a figure, and which,



Old forms of medical coils (*circ.* 1849).

according to Althaus, was the first apparatus of its kind to be used in medicine. The first to introduce the sledge for shifting the secondary coil was Du Bois Raymond, while the idea of a

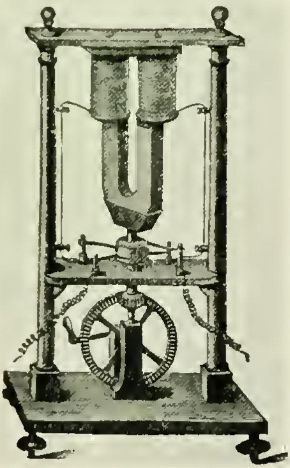


Benedict's coil.

brass tube sliding over the iron core of the primary was due to the researches of Professor Dove. A modification of Du Bois Raymond's coil, as designed by Benedict, is shown in the accompanying figure.

Magneto-Electric Machines.

Almost immediately upon the discovery of magneto-electric induction, in 1831, magneto-electric machines were devised. These, though of interest mainly from the fact that the dynamo is their lineal descendant, must have a brief consideration; firstly, because they were used for therapeutic purposes, and secondly, because they still have a certain vogue among the public who want to subject themselves to electrical treatment (?) at home. The reason for their popularity is sufficiently



Pixii's magneto-electric machine.

obvious, since, as has been remarked, "It is easier to turn a handle than to charge a battery."

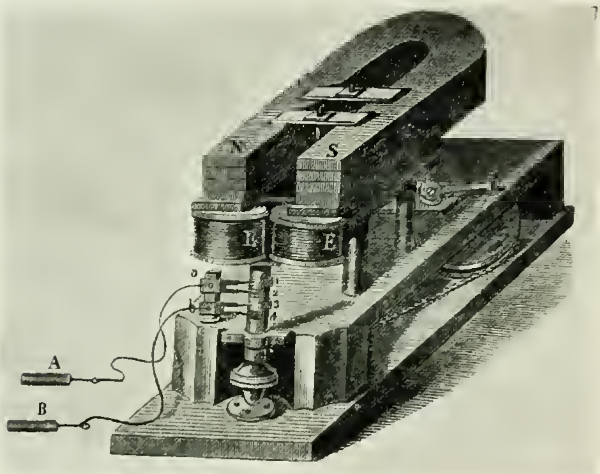
The plan of the first machine of the type we are now considering was contained in a letter directed to Faraday, and which appeared in the *Philosophical Magazine* of August 2nd, 1832. Its essential feature was an arrangement of six horse-shoe magnets, which rotated in front of six bobbins wound with insulated wire.

In September, 1832, Pixii devised a machine consisting of a horse-shoe magnet, rotated in the neighbourhood of two bobbins of wire, as shown in the figure. In order to avoid any inconveniences arising from the perpetual alterations in

the direction of the current, Pixii added a commutator to his machine.

The machine possessed the disadvantage that the heavy magnet was the rotating part of the apparatus, but about the same period Clarke devised a machine in which the bobbins formed the moving part of the system. Clarke's machine is the prototype of the popular "medical galvanic machines" which are still on the market.

A further stage in the evolution of the dynamo machine was Stöhrer's, constructed on the same lines as Clarke's



Popular magneto-electric shocking machine after Clarke's pattern.

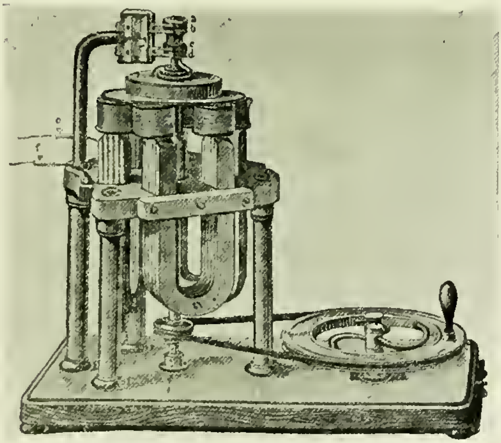
instrument, but with six bobbins instead of two, and three compound magnets in place of one. The introduction of electro-magnets in place of the old permanent magnets in such machines is due to Sniseden (1853), Wilde and others.

Machines of the type of Clarke's are, of course, not now used in scientific electrotherapy, and to discuss the evolution of dynamo machines is quite beyond the province of the present paper.

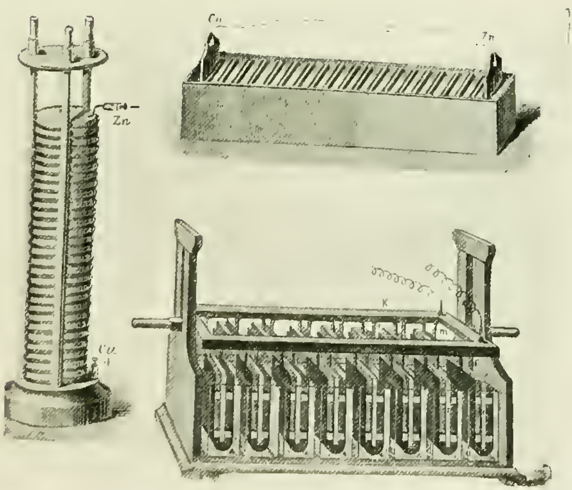
Elfctric Batteries.

Allusion has already been made to Volta's pile and the "Couronne de tasses." Cruikshank, in 1803, introduced his

battery or trough, in which a series of plates of copper and zinc were suitably connected and placed in weak acid contained in a wooden trough.



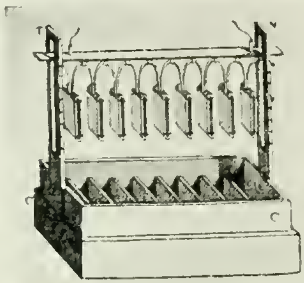
Stöhrer's magneto-electric machine.



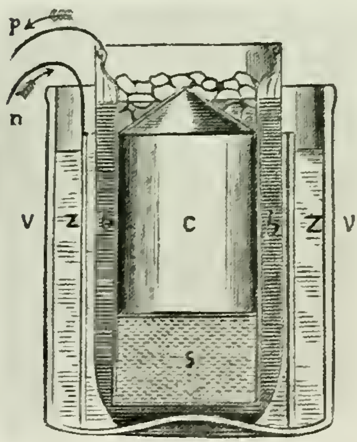
On the left is a Volta's pile; above, a Cruikshank's trough; the lower figure shows a Wollaston's battery with the plates lowered.

Wollaston modified the arrangement by placing each couple in a separate glass or porcelain cell, and fitting the battery with an apparatus by which the coppers and zincs could be

lifted out of the acid when not in use. As is well known, batteries of these primitive types were inconstant in their action and soon became polarised. The credit of the invention of the first constant cell is due to Becquerel,* who



Wollaston's battery, with the plates lifted.

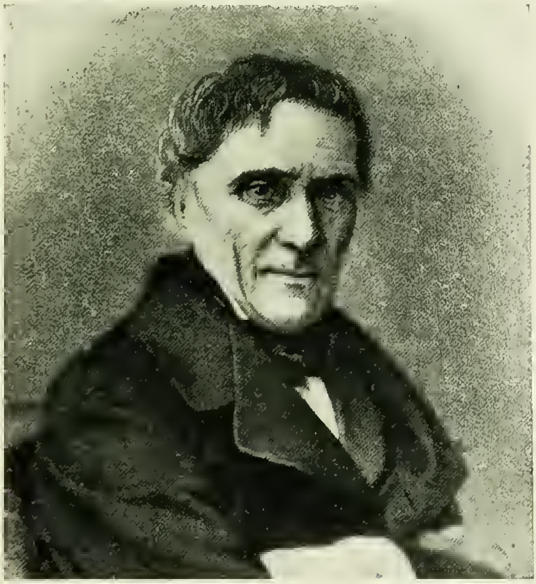


Becquerel's constant cell.

constructed a cell which was ultimately modified into the Daniell's cell. The apparatus consisted of an outer containing vessel of glass or porcelain (V), in this is placed a plate of zinc bent into the form of a cylinder (Z), in the centre of which is placed a bladder (B), containing a hollow copper

* See Note E, p. 176.

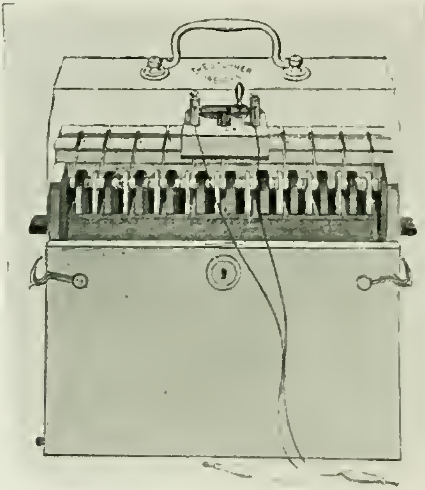
cylinder (c) and a saturated solution of copper sulphate; in the bottom of the copper cylinder is some sand (s) to keep it steady. The outer vessel containing the zinc cylinder contains also dilute sulphuric acid. It is evident that this system differs only from a Daniell's cell in having a diaphragm of bladder instead of porous earthenware. The Daniell's cell was invented in 1837. Grove's cell, in which the metals are zinc and platinum, and the liquids dilute sulphuric and strong nitric acids, was invented in 1839. It was subsequently



Antoine César Becquerel (1788-1878.)

modified by Bunsen, who substituted carbon for the expensive platinum. Smee devised his cell in 1840, and the Leclanché cell dates from 1868. The number of batteries of different makes, shapes and sizes may fairly be described as legion, and it would be impossible to give an account of them here. It may be interesting, nevertheless, to bestow a passing glance upon one or two attempts at producing a portable battery. The first of these was made by Stöhrer, of Dresden, and consists of plates of carbon and zinc immersed in dilute sulphuric acid, to which a small amount of bisulphate of

mercury is added to keep the zincs amalgamated. The cells are made of vulcanite instead of earthenware or glass, and are only half filled with liquid, and when the battery is not in use they rest on the bottom of the box containing them, so that the zincs and carbons are not immersed. When required for use the cells can be raised by means of a wooden rod, which can be fixed in position by giving it a quarter turn. Other ingenious features in this apparatus are the sledge or current selector and the commutator or current reverser.

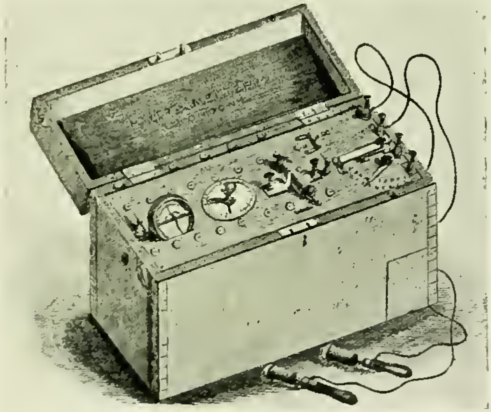


Stöhrer's portable battery.

The idea of combining a battery and an induction apparatus in the same box is due to Mayer and Meltzer, of London, the battery consisting of carbon and zinc elements in dilute sulphuric acid arranged as in Stöhrer's apparatus.

Althaus devised a portable battery (1866), which in its essential features approximated to a series of dry cells. The elements consisted of modified Daniell's cells, but the liquid was saturated with sawdust, while the earthenware containing vessels, such as were commonly in use, were replaced by cells of vulcanite. Althaus claimed that his apparatus required no attention for three months, and the weight was about thirty-five pounds.

Beetz, of Munich, designed a portable Leclanché, in which the containing vessel is an ordinary test tube. This is one-third filled with a mixture of coarsely powdered carbon and



Mayer and Meltzer's portable battery and coil.

Althaus' portable battery.

manganese dioxide, two-thirds of the tube are filled with a saturated solution of ammonium chloride, and the upper part of the inside of the tube is coated with tallow to prevent the

contained liquid "creeping up" and crystallising. The upper part is closed with a vulcanite cover, through which passes a zinc rod, while a platinum wire passing to the bottom of the tube forms the carbon pole.

It was early noticed that plates of ordinary zinc when immersed in battery liquids became corroded, even though the circuit was not closed. That this waste of material could be avoided by amalgamating the surface of the zinc plates or rods with mercury, was discovered by Matteucci in 1856.

Carlo Matteucci.

In recent years various forms of dry cell have been placed upon the market. A usual form consists of a cardboard cylinder containing a zinc cylinder, fitted with a projecting wire. This cylinder is lined with a paste made of plaster of Paris 27 parts, water 51 parts, and ammonium chloride 12 parts. A carbon rod occupies the centre, the intervening space being filled with a mixture of ammonium chloride, powdered carbon, manganese dioxide, zinc sulphate, glycerine, and water. This mixture, on standing, sets to a firm mass, so that

there is no liquid to be spilt and the cell can be used in any position.

Secondary Batteries.—Now that a public electrical supply is rather the rule than the exception, secondary or storage batteries are employed for many purposes in connection with electrotherapy. The modern forms of such a piece of apparatus are very numerous, but we may be permitted to refer to one or two historical facts in their development.

The first observation on the subject is that of Gautherot (1802), who noticed that the platinum wires used in electrolysis became polarised and absorbed oxygen and hydrogen, while upon connecting them a secondary current was produced. In 1803, Ritter devised a secondary battery by arranging a series of discs of platinum, separated by layers of cardboard, in the same way as the discs of a voltaic pile. One terminal of this arrangement was connected with the positive and the other with the negative pole of a Volta's pile. It was then found that the apparatus when disconnected from the voltaic pile was capable of furnishing an electric current. Ritter, though appreciating the importance of his observation, was unable to pursue the subject further owing to lack of funds.

The practical development of secondary batteries is due to Planté, who published his earlier researches in the *Comptes Rendues*, and gave a complete account of his work in his book, *Recherches sur l'Eléctricité*, in 1879.

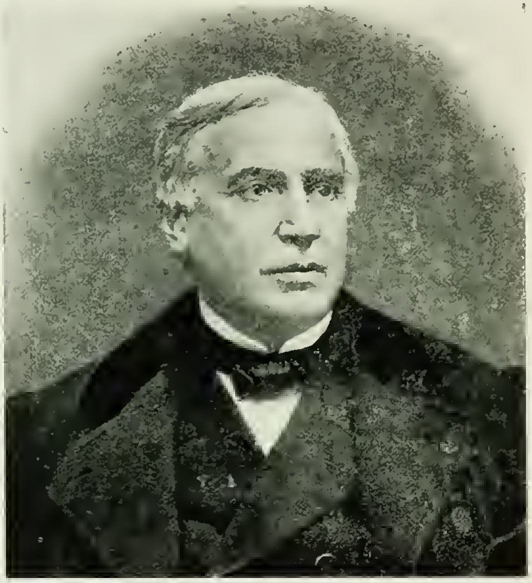
From Planté's time onwards, the development of secondary batteries has been an important feature of electrical research.

The Galvano-Cautery.

The first suggestion of the medical use of the heating power of electric currents, which I have been able to discover, is in Becquerel's *Traité de l'electricité* (1835), where he mentions that Fabré-Palaprat had succeeded in cauterising deeply-seated tissues by the introduction of a platinum needle. As was pointed out by von Middeldorpff, in 1854, there is clearly some mistake in the account of the procedure.

In 1841 Récamier and Pravaz attempted the removal of carcinoma of the cervix uteri by the galvanic écraseur, and in 1842 Dr. Crusel, of St. Petersburg, submitted a memoir on

the subject to the Académie de Médécine of Paris. In 1846 Heider, of Vienna, employed the galvano-cautery for the destruction of nerves in dental operations, and after the publication of his paper many other surgeons used it on a limited scale. In 1850, Nélaton, for whose work Regnauld devised a special battery, employed the galvano-cautery successfully for the removal of growths which were difficult of access, such, for example, as those occurring in the



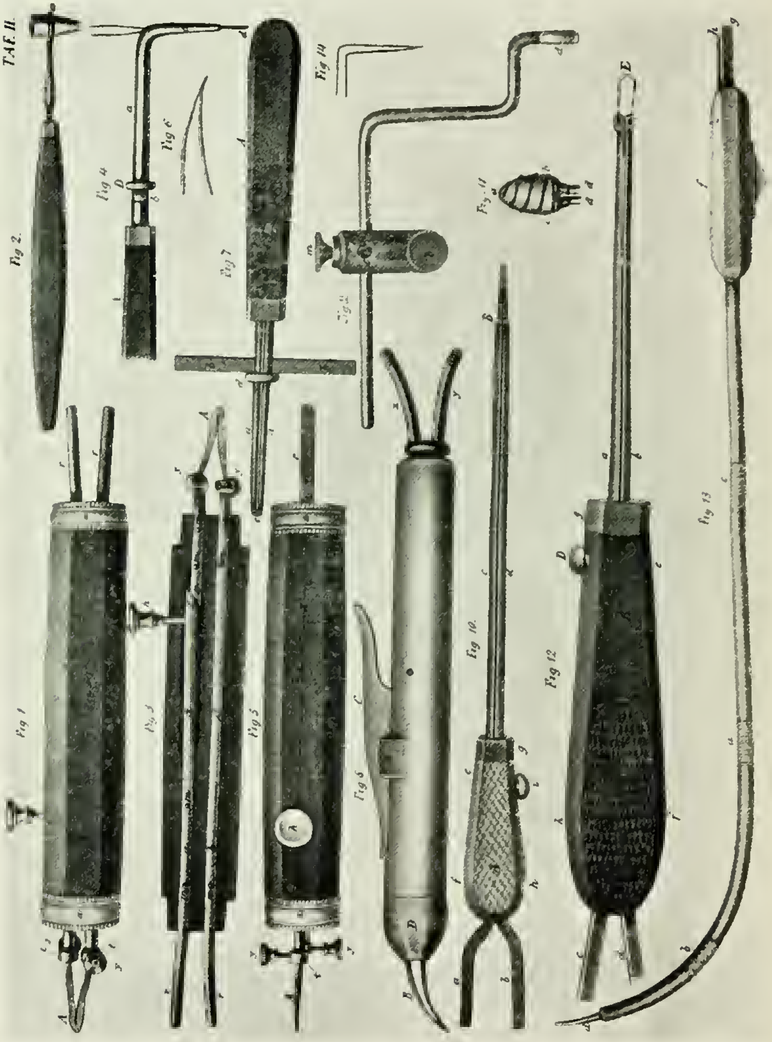
Auguste Nélaton.

pharynx. Nélaton was also successful in treating erectile vascular tumours by the same means.

The first use of the galvano-cautery in this country was by John Marshall, assistant surgeon to University College Hospital, on Nov. 5th, 1850. The case was one of a chronic fistula in the cheek, which ensued upon a local suppuration and obstinately resisted treatment for a year. Various operations had been tried, and it was eventually decided to cauterise it. To use an ordinary cautery in a long, narrow, winding fistulous track seemed impossible, and some other expedient

had to be devised. In Marshall's own words, "It then occurred to me that a piece of platinum wire, which might be easily passed through the narrowest and most tortuous passage, might, by being made to form part of the circuit of a powerful galvanic battery, be so intensely heated throughout its whole length, while still lying in the fistula, as most effectually to cauterise every portion of its inner surface." Before operating on the patient, Marshall made a number of experiments on dead animal tissue, and on anæsthetised rabbits and dogs. The battery used consisted of four Grove's cells, and the experiments proving satisfactory it was decided to test the efficacy of the method on the patient. The following is the description of the operation, as given by Marshall himself: "The practicability and safety of cauterisation by the heat of electricity being thus established, I proceeded, on the 5th of November, in the presence of Professor Sharpey and Dr. Ditchfield, to submit my patient to the following operation. The same battery was employed as before. One of the poles was interrupted, the broken end terminating at a mercury cup; a fine platinum wire, $\frac{1}{50}$th of an inch thick, was passed leisurely, and without producing pain, through the fistula, until it appeared in the mouth of the patient. The part of the wire outside the cheek was then twisted on to one of the stout copper poles of the battery, whilst the other end, visible at the inner orifice of the fistula, was brought into contact with the other pole, which for that purpose was passed into the mouth. During these arrangements the circuit of the battery remained open. The patient, who had not taken chloroform, was now desired to keep quiet and allow his head to be firmly held. The galvanic circuit was then closed by dipping the interrupted pole into the mercury, when the platinum wire instantly became heated; and at the expiration of nine seconds the circuit was broken, the cauterisation being supposed, from previous experience, to be, by that time, sufficiently complete. Both orifices of the fistula would now have admitted a crow-quill, and were surrounded by a well defined, opaque, whitish eschar. The patient expressed himself surprised at the small amount of pain produced by the operation; he had felt a sense of burning upon his cheek, and of pricking within the mouth;

but no pain along the fistulous track." The patient made a good recovery, and eleven days after the operation healing was complete.



Von Middeldorpff's galvano-cautery instruments.

The development of the electro-cautery and the prototypes of most of the apparatus now in use, we owe to Albrecht Theodor von Middeldorpff, of Breslau, who published a

systematic treatise on the subject in 1854. Middeldorpff is also known as the editor of the first printed edition of Heinrich von Pfolsprundt's *Bundth-Ertznei*, the first German book on surgery, written in 1460, but remaining in manuscript until 1868. This work is interesting from the fact that its author, a Bavarian army surgeon, makes the earliest known allusion to powder burns and the extraction of bullets.

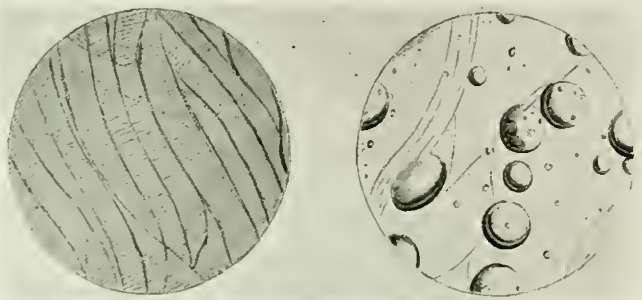
Voltolini, of Breslau, was the first to use the wire loop for the removal of intra-laryngeal tumours (1865).

The dangers of pre-Listerian hospitals are forcibly brought to mind by an account given by Zielewicz of fifty cases of amputation of the penis by the galvanic écraseur. In private cases not a single death occurred, but in hospital practice no less than eight cases died of pyæmia. Althaus, in reporting this, says, "The danger lies in the laxity of the cellular tissue of the penis, the veins of the neck of the bladder and the prostate, and in the influence of noscomial air." He adds, however, that a free use of carbolic would probably neutralise the effects of "noscomial air."

Electrolysis.

The first systematic work upon the therapeutical possibilities of electrolysis was carried out by Althaus, of London, who published his results in 1867. His researches commenced with microscopical examinations of tissues, into which were inserted needles connected with the terminals of a suitable battery. He attributed the destructive action occurring in the immediate neighbourhood of the negative electrode to two factors, namely, a chemical effect due to the liberation of free alkali, and a mechanical effect produced by the escape of minute bubbles of free hydrogen. After a series of careful experiments upon living and dead animal tissues, he performed his first electrolysis operation on the human subject in July, 1866. The patient was a young lady with a nævus on the eyelid, and as she was very nervous it was decided to put her under chloroform. A needle connected with the negative pole of a battery of ten cells was inserted into the right half of the tumour (which was of the size of a small pea), while the positive pole of the battery was connected with a moistened

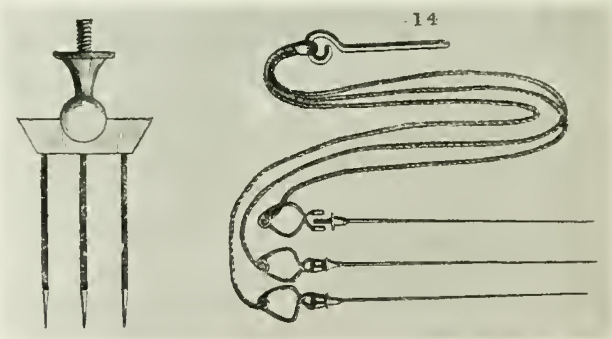
electrode applied to the skin of the neck. The current was allowed to pass for two minutes, and when the needle was withdrawn the right half of the tumour seemed shrunken while the left was unaffected. The left half was operated upon by the same method within the month, this time without any



Microscopic appearances of muscular tissue, before and after electrolysis (Althaus).

anæsthetic, the final result of the treatment being completely satisfactory.

This method of treatment was applied to other conditions, such as malignant growths and hydatids, and it was suggested

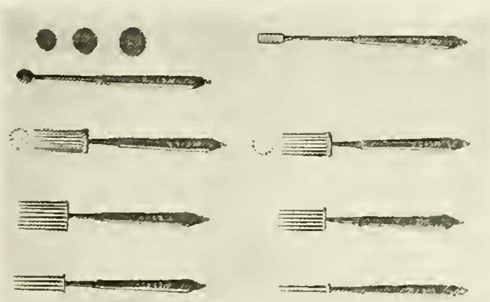


Needle-holders for electrolysis (Althaus).

as worthy of a trial in cases of pleural effusion in place of paracentesis. The last suggestion seems peculiar, but it must be remembered that those were pre-antiseptic days, and Althaus quotes a warning by Addison, of Guy's, which was given in 1855, respecting aspiration of the pleural cavity:

"A serous cavity is almost invariably changed into a cavity pouring out purulent matter by the first operation, and the thick leather-like false membranes lining the pleura soon make the operation one of great difficulty and danger."

General Faradisation. Operator's hand used as one electrode (Althaus).



Various forms of electrode or electrolysis (Althaus).

Another condition for which Althaus designed a special form of electrode was œsophageal stricture. The apparatus consisted of an œsophageal sound, perforated so as to transmit a conducting wire ending in a needle, which could be extruded when the required spot in the œsophagus was reached

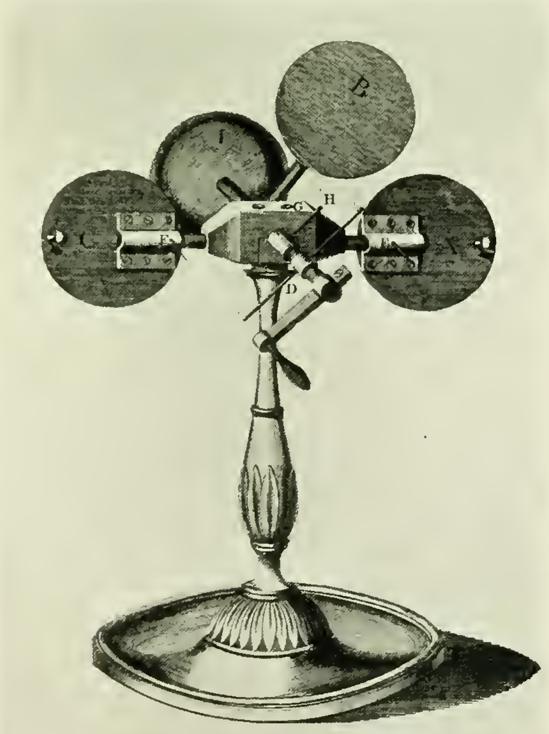
The special contribution made by Althaus to this branch of electrotherapy was the recognition of the action of the negative electrode and the designing of various forms of needle and holder. What was known as "galvano-puncture" had frequently been tried upon aneurysms but with unsatisfactory results. In this procedure one or more pairs of needles were passed into the aneurysmal sac and suitably connected to both poles of the battery. In one case described two pairs of needles were used, the direction of the current being reversed every five minutes, while the total duration of the procedure was twenty-five minutes. Loose clots appear to have been produced by this method, and there was also considerable danger of hæmorrhage at the site of puncture.

The application of electrolysis to the removal of superfluous hairs on the face is due to an American ophthalmologist, Dr. Michel, of St. Louis, who first practised it in 1875. Other workers in this field were Piffard, Hardaway, and Fox (of New York). At first it was usual to extract the hair before destroying the hair follicle, but Fox, in 1882, introduced his needle by the side of the hair and operated with the hair *in situ*. The negative electrode consisted either of a very fine needle, such as is used for dental purposes, or a piece of platinum wire filed until it terminated in a very fine point.

Influence Machines.

Rather more than two hundred years after von Guericke had mounted his sulphur ball to make the first frictional electric machine, Holtz constructed the induction machine which bears his name (1865), which is still largely used in America. So far back as 1762 Wilke had performed experiments upon induced electricity with glass plates, but it was not till 1775 that Volta constructed his Electrophorus, "for the purpose of procuring, by the principle of induction, an unlimited number of charges of electricity from one single charge" (Thompson). By suitable mechanical means the production of these inductive charges can be made practically continuous, and the earliest form of such a continuous electrophorus was Bennet's Doubler, while its latest developments are seen in modern influence machines. Other influence machines are those of

Toepler, Voss, Carré, and Wimshurst, which last machine, invented in 1883, is the form of apparatus most favoured in this country. Holtz's machine in its original form consists essentially of two circular glass plates, one of which is slightly the larger and is fixed. The other, slightly smaller, is fixed to a vulcanite axle, which allows it to rotate parallel and close to



Bennet's Doubler. The first Influence Machine (1789).

(but not touching) the larger fixed plate, through an aperture in the centre of which the axle passes. Towards the extremities of one of the diameters of the fixed plate are cut two windows, and on the side remote from the revolving plate are two strips of paper, each of which is fixed along one of the windows, and from each of which projects a pointed piece of card into the middle of the corresponding window.

The glass disc and the paper mountings are coated with sealing wax.

Two metallic conductors furnished with pointed teeth are placed as near as possible to the revolving plate, but without touching it; each of these has a metallic stem, parallel to the

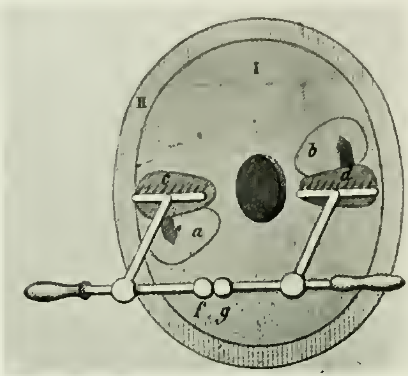
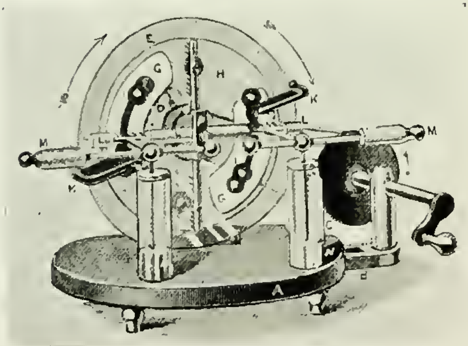


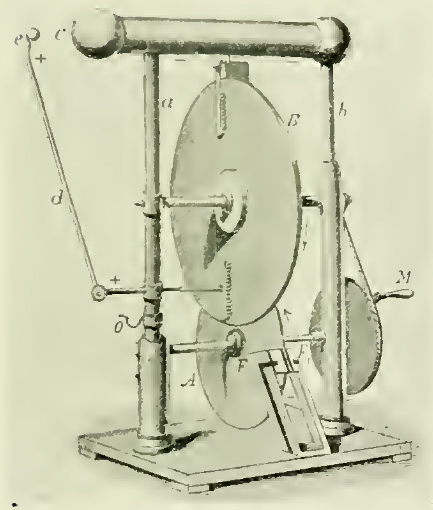
Diagram of Holtz Machine.



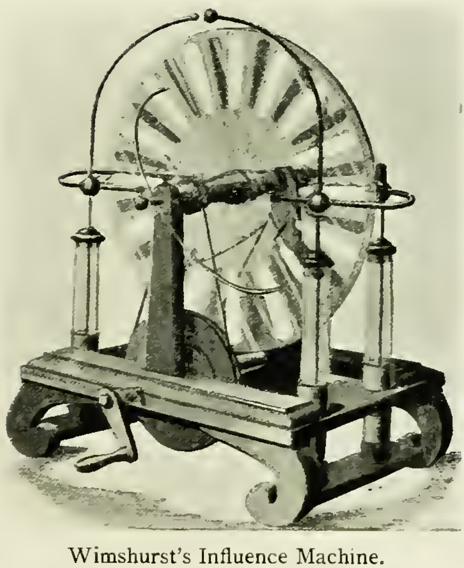
Voss' Influence Machine.

axle and therefore at right angles to the plates; these terminate in the electrodes of the machine.

To set the apparatus to work, the electrodes are placed in contact, and the movable plate rotated by the handle; a charged piece of vulcanite is brought near to one of the paper strips and removed as soon as a crackling sound is heard. The rotation must be performed so that the several sections of



Carré's Machine.



Wimshurst's Influence Machine.

the revolving plate *first* pass the windows, and then the paper strips of the fixed plate.

Carré's machine, which is a combined frictional and induction machine, had a great vogue in France.

Owing to atmospheric conditions, static machines are much more commonly used in America and on the Continent than they are in this country.

Revival of Electric Treatment at Guy's Hospital.

In October, 1836, an "Electrical Room" was started at Guy's Hospital, and in the succeeding years a thorough investigation was made and careful reports were issued of the value of different forms of electrical treatment in various disorders. Golding-Bird, Addison and Gull are the most prominent names in this connection.

In 1837, Addison published his article on the influence of electricity in various "convulsive and spasmodic diseases." The majority of the patients were women, in whom the troubles were attributed to uterine disorders, and the treatment consisted in drawing sparks up and down the spine, or in passing shocks from Leyden Jars through the pelvis. In the first case the patient was placed in an insulated chair and metallic connection made with the prime conductor of a frictional machine. A brass ball, furnished with a chain connecting it to the earth, was then passed up and down the spine at a distance of about one inch. This was continued until a red eruption (" like lichen urticatus ") followed, which in the majority of patients required from five to ten minutes. For administering the shocks a large Leyden Jar was placed so that its inside coating was connected with the prime conductor, a Lane's electrometer being fitted into one end of the latter, so that the insulated ball of the electrometer could be placed either in contact with or at any desired distance from the prime conductor. A chain was fitted in contact with the outer coating of the jar and another chain was attached to the ball of the electrometer. Both chains terminated at their free extremities in directors, which could be applied to the patient as desired, one being placed on the symphysis pubis and the other on the sacrum. A footnote informs us that, " There is

a female in attendance for the purpose of adjusting that part of the apparatus more intimately connected with the person of the patient." *

In 1841, Golding-Bird issued a report on the value of electrical treatment, which was followed, in 1852-53, by a

Golding-Bird.
(From the bust in Guy's Hospital Library.)

second report from Gull (afterwards Sir William Gull). These records were models of careful investigation and reporting, and

* There is a good deal of history here in a very few words. "Martin Chuzzlewit," in which Mesdames Gamp and Prig made their appearance, was published rather after the date of this paper (in 1843), and one is tempted to speculate upon the type of "female" to whom reference was made. It would hardly facilitate the harmonious working of a modern department to refer to the sister-in-charge as "a female" in the Hospital Reports.

attempts are made to classify the cases which had received, or which had not received, benefit from the treatment.

The Reports of the same hospital for 1848-9 contain a paper by Skinner, describing the use of the galvanic battery to induce labour in a case of placenta prævia. One electrode was placed in the neighbourhood of the fundus uteri and the other in the groin, their relative positions being occasionally reversed. The electricity was applied at 10.45 a.m. for half an hour and then stopped for twenty minutes, when it was re-applied. The patient was delivered of a still-born child at 12 noon.

In 1851, Lever, also of Guy's, unsuccessfully endeavoured to induce premature labour by electricity in a patient with a deformed rickety pelvis. In this case, one electrode consisted of an iron rod coated with leather and ending in a brass ball, which was introduced *per vaginam*, so that the brass ball touched the os uteri, the other terminal being applied over the region of the fundus. In this case the faradic current was used, but though repeated on three successive days no effect was produced, and labour was induced by rupturing the membranes.

In 1872, Wilks treated a case of plumbism by the electric bath. A bath lined with tiles was used, and sufficient sulphuric acid was added to the water to give it a faintly acid taste. A copper plate, 2½ feet square, was immersed in the bath so as not to touch the patient, and connected to the negative pole of the apparatus, an electrode connected with the positive pole being grasped by the hand of the patient, held out of the bath. The constant current was used in this case, from fifty to eighty cells being used. The treatment was repeated three times, and on each occasion the patient reported that he felt better.

Some Queer Ideas about Electricity.

Electricity has always been a happy hunting ground for theoretical speculators, and unfortunately for quackery as well. Some of the curious notions we are about to notice were the genuine speculations of learned men, while others were, to say the least, decidedly questionable in their honest intent.

Professor Boze, in the eighteenth century, published far and

wide the account of an experiment, which was termed the "Beatification." He affirmed that by the use of a suitable electrical machine, an insulated person when electrified would exhibit a radiating flame extending from the feet upwards and around the head in the way a "glory" is depicted around the heads of saints. The experiment was repeated by other electricians, but without success. At last Dr. Watson, of London, wrote to the professor, and obtained an acknowledgment that the whole thing was a trick, and that he had made use of a suit of armour fitted with projecting buttons, bosses and points.

We have already alluded to Dr. Watson's part in controverting the statements of Pivati, Winckler and others, which certainly very nearly approach the border line of quackery, even if they do not transgress it.

Of a very different type were some theories advanced by John Freke* (1688-1756), who was surgeon to St. Bartholomew's Hospital, and the first curator of the museum. The museum at that time consisted of a collection of calculi removed by lithotomy and preserved in a room under the "cutting ward." † In 1748 he published an essay on electricity, in which he advanced the view that the movements of the leaves of the sensitive plant were due to electricity. His experimental evidence was derived from insulating a small plant placed in a pot, upon a cake of resin. Upon electrifying the plant the leaves stood out, and he hence assumed the same cause as explaining the movements in the sensitive plant. Another of his ideas was that the insects found in "blighted"

* He was a very versatile man, and in 1735 carved the oak chandelier which still hangs in the Steward's Office at St. Bartholomew's Hospital. The following extract from a footnote to Thackeray's "English Humourists," (Art. Hogarth) may be of interest. "Hogarth, being at dinner with the great Cheselden and some other company, was told that Mr. John Freke, Surgeon of St. Bartholomew's Hospital, a few evenings before, at Dick's Coffee-house, had asserted that Greene was as eminent in composition as Handel. 'That fellow, Freke,' replied Hogarth, 'is always shooting his bolt absurdly, one way or another. Handel is a giant in music; Greene only a light Florimel kind of composer.' 'Aye,' says our artist's informant, 'but at the same time Mr. Freke declared you were as good a portrait painter as Vandyck.' '*There* he was right,' adds Hogarth, 'and so, by G——, I am, give me my time and let me choose my subject.'" (Hogarth's *Works*, by Nichols and Steevens, Vol. I., pp. 236, 237.)

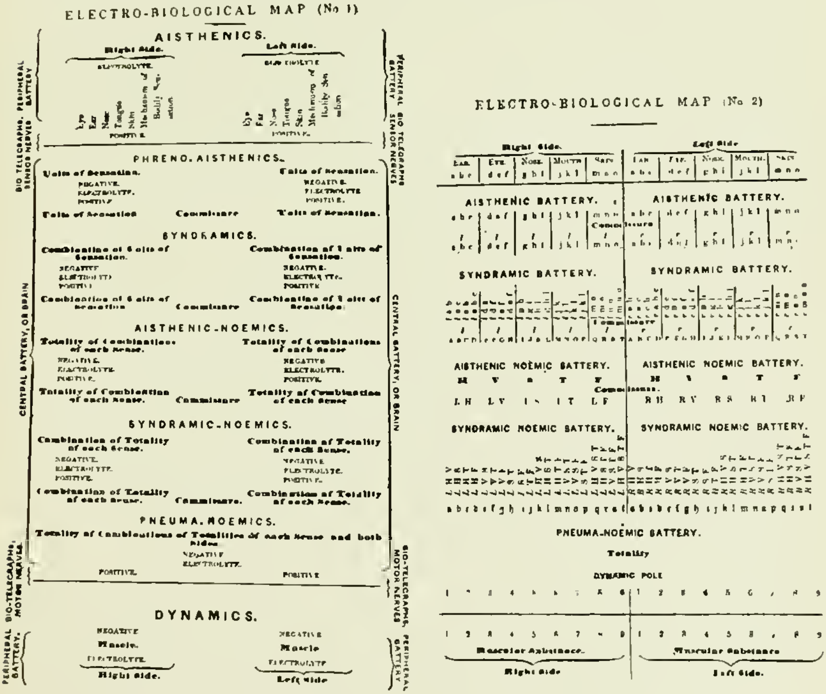
† Another room "under the cutting-ward" was also set aside to—*receive the dead!*

plants were conveyed thither by the action of electricity; and acute rheumatism was, according to him, produced by the same agency. This electro-pathology, if the expression be permissible, was greatly elaborated by the Abbé Bertolon, in a work called *De l'électricité du Corps humain*, published in 1780. This author regarded the human body as absorbing electricity from the atmosphere through the pores of the skin and the lungs. Having calculated to his own satisfaction that 1,152,000 cubic inches of air entered the lungs daily, he assumed the imbibition by the same channel of atmospheric electricity. He made an elaborate classification of diseases into species and genera, which were arranged in ten classes. These diseases were supposed to be due to the influence of positive or negative electricity, and therefore to be curable by electricity of opposite sign, and an attempt was made to establish a relation between the birth and death rates and atmospheric electrical conditions.

Dr. Cavallo, in his account of the Abbé's work, suggests that one "must naturally suspect that the author of the above mentioned work has indulged his fancy too much." Dr. Cavallo was one of the writers who endeavoured to stem the advancing tide of irresponsible and exaggerated statements which were bringing the whole subject of electricity into ridicule and disrepute. From this standpoint it may be noted that he is consistent in his advocacy of the use of the electric shock in aborting an attack of ague. There does not seem much doubt that genuine malaria is meant, since he advises that the shock should be administered immediately before the expected return of the attack. In this contention he is supported by several other authors of the period.

It had long been a speculation whether electricity had any smell, and in 1851 Schönbein, who was introduced by Faraday, read a paper before the Royal Medical and Chirurgical Society upon the subject. He proved the formation of nitric acid as the result of the electrical discharge, and conformed to the view of Berzelius and de la Rive that the powerful deodorising and oxidising agent, which is produced at the same time, was ozone and not, as he had previously held, a modification of hydrogen peroxide. He noted the irritating properties of

ozone, and, in conjunction with the physicians of Bâle, undertook investigations to determine whether any relation existed between the incidence of catarrhal diseases and the quantity of ozone present in the air. For the detection of ozone potassium-iodide-starch papers were used, which of course became blue when moistened and exposed to ozone; Schönbein recorded that the incidence of nasal catarrhs was greatest on

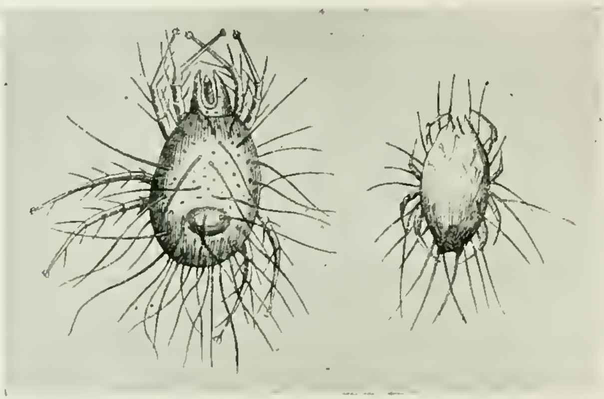


Two "Electro-biological Maps," from Smee's *Electrobiology* (1849).

his "blue days." He, however, noted that ozonised air destroyed the "miasmatic substances" exhaled from such material as putrid meat. One confirmation of the fact that ozone is responsible for the odour accompanying electrical discharge is recorded in the same paper. An engineer named Buchwalder was employed upon some work on the summit of the Senlis, and during a thunder-storm his tent was struck and his servant killed. Upon subsequently visiting Schönbein in his laboratory, where the latter was employed in some

experiments with ozone, the engineer at once identified the smell as the same which he had noticed when his tent was struck.

In 1849, Arthur Smee, F.R.S., published his *Elements of Electrobiology*, an extraordinary little book, in which he advances elaborate electrical theories of most of the phenomena of life, physical and psychical, even deviations from moral rectitude are attributable to abnormal electrical conditions. As may be imagined, the whole book forms curious reading, and not the least curious is the section in which he discusses the question as to whether life can be generated *de novo* under the influence of electricity, and says that, "It now becomes a



"Acari" figured by Cross (L) and Weekes (R).
(Smee's *Electrobiology*, 1849.)

matter for investigation how far a totally different organic being may spring from another organic body made up of cells." He regards it as an open question if parasitic fungi (such as ringworm), tapeworms and hydatids are generated by some unknown agency from the cells of their host, or whether they are "conveyed thither by some unknown method." He next proceeds to quote some experiments made by Cross and Weekes upon the spontaneous development of acari by the action of the electric current upon different solutions, giving pictures of an acarus as discovered by each observer, and adding in a footnote that he was recently the recipient of a letter from Mr. Weekes, in which he claimed to have produced two further species of acari by this method. He frankly adds

that he himself had been unable to succeed in his attempts at the production of acari by electricity. "Now I tried somewhat similar experiments to see if any creature appeared, but have never observed anything of the kind which could at all be traced to voltaic origin. But these experiments deserve frequent repetition by those who have the abundant funds of rich institutions at their disposal."

In 1859 Beckensteiner developed a theory that static electricity should be "animalised" by passing it through the body of the operator before applying it to the patient, and that the Pacinian corpuscles played an important part in the process. Moreover, he regarded metals as being "etherealised" by the passage of electricity, and hence conductors of different metals would produce different effects. According to this author, iodine, valerian, asafœtida and musk could be introduced into the human body by the action of static electricity; this is, of course, to some extent a revival of the crudities of Messrs. Winckler, Bianchi, Pivati and others in the eighteenth century, and also a foreshadowing of the ionic medication of the present day, though needless to say, the results claimed rested upon no experimental evidence.

A doctor of Cracow, with the singular name of Dropsy, was the first to recommend general faradisation (1857), "but his proposal was supported by such singular reasoning as to provoke more ridicule than serious attention. He says that he has discovered a physiological formula for the distribution of electric sensibility through the body, according to which the top of the head is most sensitive, and a gradual decrease of sensibility takes place towards the feet. This formula is, according to Dropsy, altered in disease, and the object of treatment is to change the pathological into the physiological formula." All curable diseases were to be alleviated by these means, disease being due simply to deviations from the law, while conversely recovery was due to its re-establishment.

Seiler, in 1858, described what he termed "galvanisation by influence"; the electrodes were not applied to the patient's body either directly or indirectly, but, being held in the operator's hands, were waved in the air in different directions at a short distance from the patient.

In more recent years we have seen exposures of various quack "electrical" remedies in the shape of belts and other articles. Anti-rheumatic rings, according to some, depend on electrical action for their efficacy (?); as a matter of fact, they are almost undoubtedly the lineal descendants of the old "cramp rings," which used to be blessed by the kings of England. "Cramp" in this case probably originally meant epilepsy, but seems to have afterwards been applied to local muscular contractions, especially when these were attended with much pain. Andrew Borde writes thus in his "Breviary of Helthe" (1547); "The Kinges maiestie hath a great helpe in this matter in halowynge crampe rynges and so giuen without money or peticion. Also for ye crampe take of the oyle of lilies and castory, if it do come of a cold cause. Yf it do come of a hote cause anoynte the sinewes with the oile of water lilies and willowes and roses, if it do come of any other cause, take of ye oile of euforbium and castory and of piretory and confect or compounde all togyther and anoynt ye place or places with the partes adjacent."

Superstition is still rife, and anti-rheumatic rings, though unblessed by the king's majesty, can still be purchased. Only last year I was told that it was "strengthening" to carry a common horse-shoe magnet in the pocket, and a few weeks ago I saw some Kaffir bangles, made of iron and brass wire, which were stated by the vendor to be used by the Kaffirs for warding off evil spirits, with the added note that they are galvanic; stress being laid on the latter point.

Duchenne.

Lister is not more unquestionably the founder of modern surgery than is Duchenne of modern electrotherapeutics. Guillaume Benjamin Amand Duchenne (1806-1875), often called from his birthplace, Duchenne de Boulogne, was born of a family of sailors, and indeed, his father had intended him for a seafaring life. While at school he developed a taste for science, and on leaving was sent to Paris to study medicine, where he graduated in 1831. He returned to his native town, and after practising for eleven years, again took up his residence

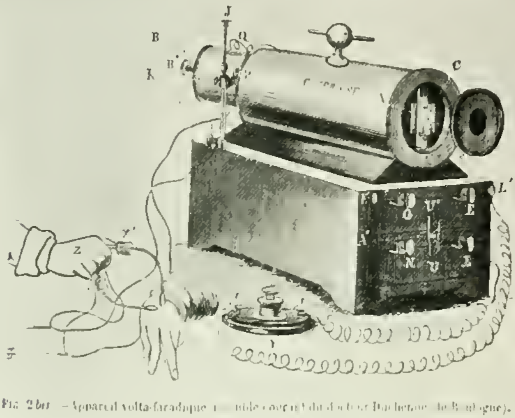
in Paris in 1842, and there devoted himself to his life-study, electrotherapy and neurology.

At first his path was beset with difficulties. A brusque manner, coupled with shyness and diffidence in expressing himself at consultations and meetings, was in itself no small disadvantage ; along with this, he was by no means a "reading-man," preferring to go his own way and make his own observations, totally regardless of any previous workers

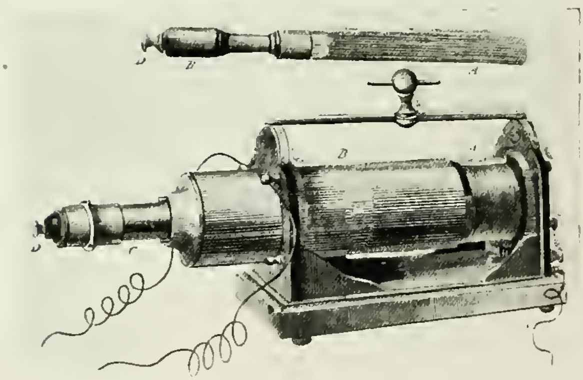
Duchenne and a patient.

in the same field, an unfortunate characteristic, which on more than one occasion landed him in useless controversy, and this in turn did not tend to facilitate matters. In addition to these personal idiosyncrasies be began to make a special study of the "paralytic" patients in the different hospitals, and it was here that more difficulties arose. At the time we are speaking of, the term "paralysis" was one of those convenient dust-bins of ignorance, which their owners are exceedingly unwilling should be disturbed. Nothing was known of either the pathology or the treatment of the varied

conditions which were hopelessly confused under this common designation. "Once a paralytic always a paralytic," seemed to be the established formula, with possible exceptions in



Duchenne's coil and battery.

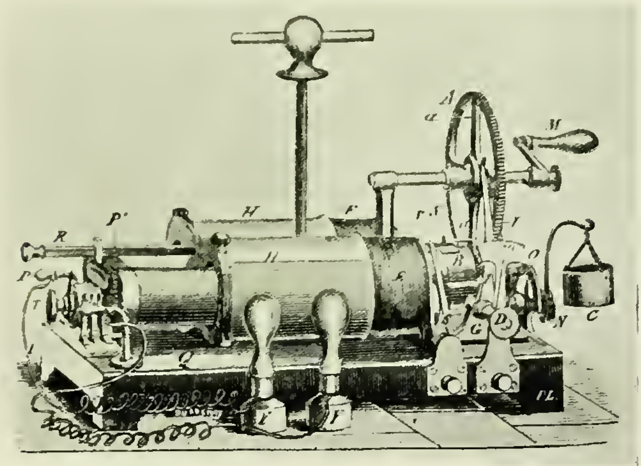


Duchenne's induction coil (*De l'electrisation localsée*, 1855).

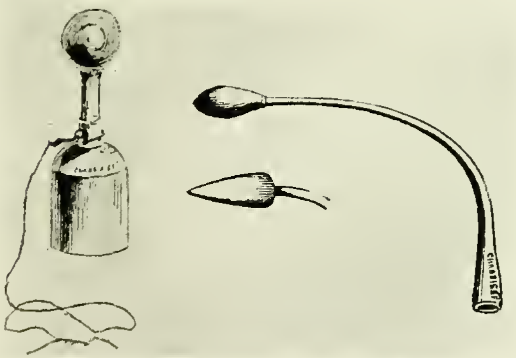
favour of miraculous cures; and it was decidedly disconcerting to those who had pronounced certain cases hopelessly incurable that they should be found walking about the wards.

Gradually Duchenne succeeded in making his way, and his sincerity and earnestness of purpose were recognised; but

more was wanted, namely, a lucid and forceful presentment of his work. In this he was helped by his friend Trousseau, who was, as Garrison says, "a man of big personality, a great



Duchenne's magneto-electric machine.



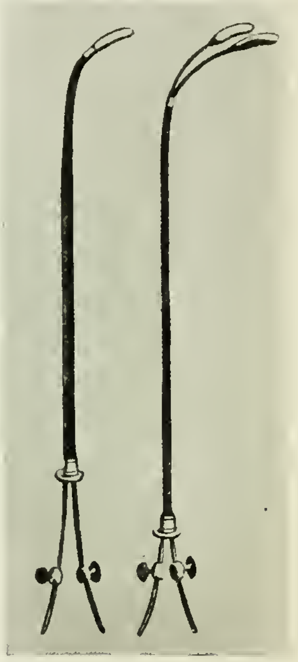
Different forms of electrode (*De l'electrisation localisée*, 1855).

master of clinical delineation, and a generous interpreter of the ideas of other men, particularly of the diseases described by Bretonneau, Addison, Hodgson, and Duchenne of Boulogne."

A systematic thoroughness was the characteristic of

Duchenne's work; every detail of the apparatus he used was criticised, old forms were modified and new forms invented. These are described at length in his work, *De l'electrisation localisée* (1855). His magneto-electric machine is a very complicated-looking affair, and is fitted with a commutator and an arrangement for regulating the number of interruptions. As a matter of fact, this piece of apparatus does not seem to have been used by anybody save its inventor.

Duchenne's electrode applied to the face.



Duchenne's electrodes for the interior of the bladder.

Duchenne was the first to discover that individual muscles can be stimulated by the application of suitable moistened electrodes to the overlying skin, and these were designed of different forms according to the various regions to which they were adapted. Duchenne's discovery was of fundamental importance for the development of both therapy and diagnosis.

Jallabert, of Geneva, had noted the phenomenon of muscular contraction as a result of electric stimulation in 1758, and

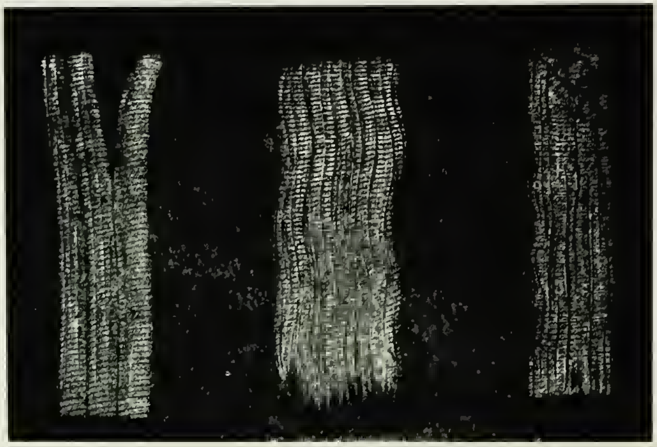
Beccaria had produced contraction in the exposed thigh muscle of a cock about the same date. Sarlandrière, in 1825, attempted to produce local muscular contractions by inserting needles (which served as electrodes) through the skin. These needles were designedly passed so as to avoid the main nerve trunks. Magendie, about the same time, made similar attempts, but instead of avoiding the nerves he purposely transfixed them. Such procedures had obvious disadvantages, and, in addition to the probability of abscess formation, which was common to both methods, persistent and intractable neuralgia was noticed—at least in some cases—as a sequel to Magendie's nerve transfixion. Duchenne, by employing suitably-shaped electrodes, fitted with moistened sponge or soft leather, and applying them to the skin, found he could obtain contractions of the subjacent muscle, and, moreover, that certain points on the skin when stimulated gave the best results. To these points he gave the name of "points d'election," but without determining their true significance, and it was left for Robert Remak, in 1855, to demonstrate that they corresponded to the entrance of motor nerves. The matter was further investigated by von Ziemssen (1829-1902), who, in 1857, carefully mapped out the whole surface of the body, marking the motor points on the skin by silver nitrate, and verifying his clinical observations by dissection immediately after death, before muscle and nerve had lost their excitability.

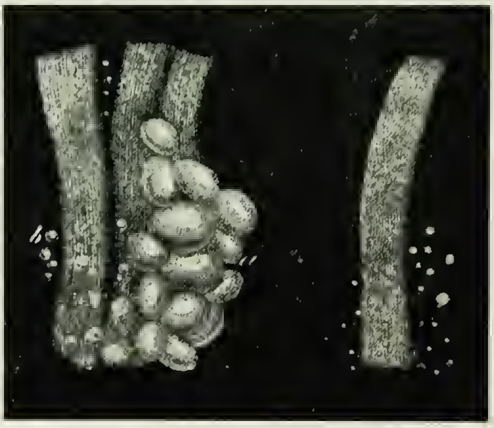
Duchenne communicated his discovery to the Académie des Sciences at Paris, in 1847. In 1855 he localised the primary lesion of anterior poliomyelitis in the anterior cornua of the spinal cord, and from 1847 to 1861 was busy working upon spinal progressive muscular atrophy of the Aran-Duchenne type. Glosso-labio-laryngeal palsy was described by him in 1860, and pseudo-hypertrophic muscular paralysis in 1868.

As we have said, Duchenne was no great reader, and consequently his important work on the anatomical lesions of locomotor ataxia (of which he recognised the syphilitic origin) involved him in futile discussions and arguments.

"He cared little for book knowledge, and knew nothing of the work of Steinthal and Romberg, let alone the fact that

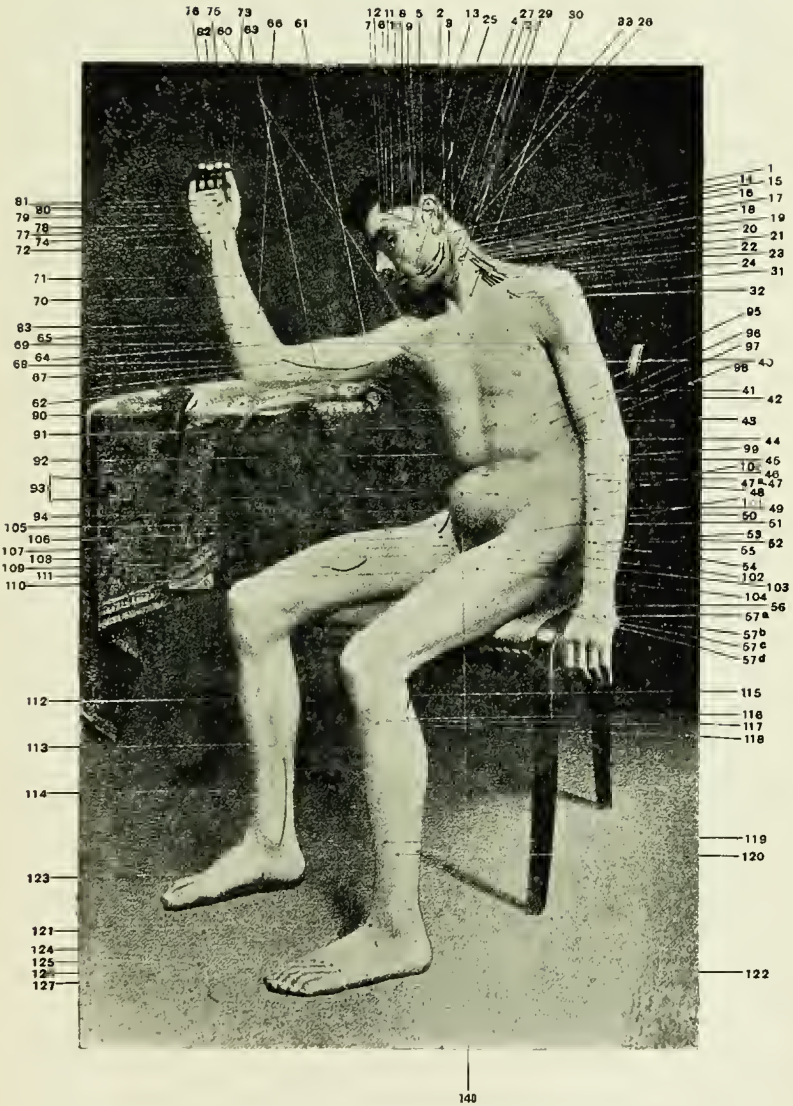
Edward Stanley had described disease of the posterior columns of the cord in 1839, and Sir William Gull, in 1856-1858. In 1858-1859, Duchenne described the disease at full length,





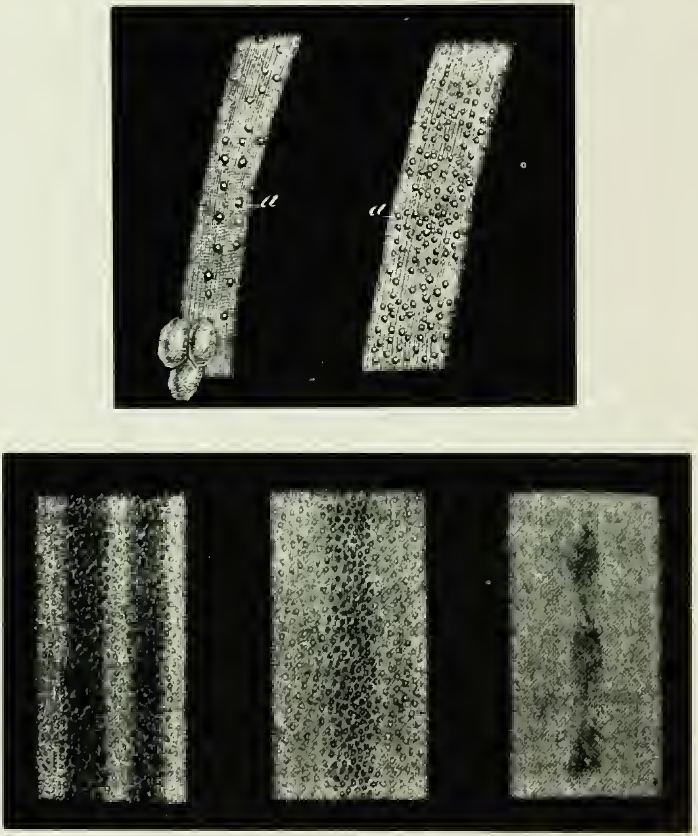
Figures (drawn by Mandl) illustrating muscular changes in spinal progressive muscular atrophy of the Aran-Duchenne type from the normal muscular fibre to its conversion into a homogeneous fatty mass (*De l'electrisation localisée*, 1855).

differentiating it from the paralyses, demonstrating the lesion in the cord, and pointing out that it is due to lues. When he heard of the work of the German clinicians, he contended that the ataxies observed by them were not the same as he had



Von Ziemssen's motor points.

seen, and so obscured the subject in controversy" (Garrison). During the last four years of his life he suffered from cerebral troubles, due to arterio-sclerosis, and died in 1875 almost forgotten. Singularly little was known of this master of



Figures (drawn by Mandl) illustrating muscular changes in spinal progressive muscular atrophy of the Aran-Duchenne type from the normal muscular fibre to its conversion into a homogeneous fatty mass *(De l'electrisation localisée*, 1855).

medicine, until Dr. Collins called attention to his life in 1908; and in his careful and sympathetic article on "Duchenne," in the *New York Medical Record*, he stated that when visiting the grave, at Boulogne, he found it overgrown with weeds and thorns.

Robert Remak (1815-1865), distinguished as a worker in physiology, histology, and embryology, made a special study of the action of the continuous current, and published a summary of his work in this connection in 1858. In embryology he is known as the originator of the terms ectoderm, endoderm and mesoderm; while in histology the non-medullated nerve fibres are also known by his name, having been first described by him in 1838, as were the ganglion cells in the frog's heart in 1848. To Remak we also owe the first description of ascending neuritis (1861). In electrotherapy his great work

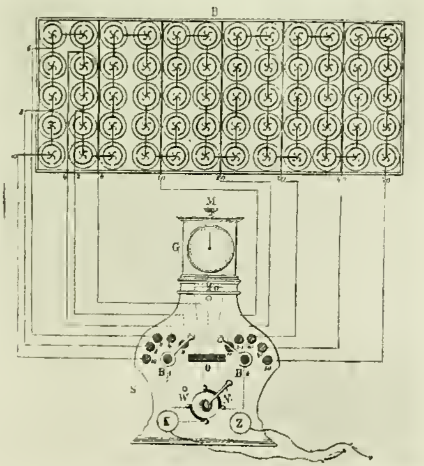


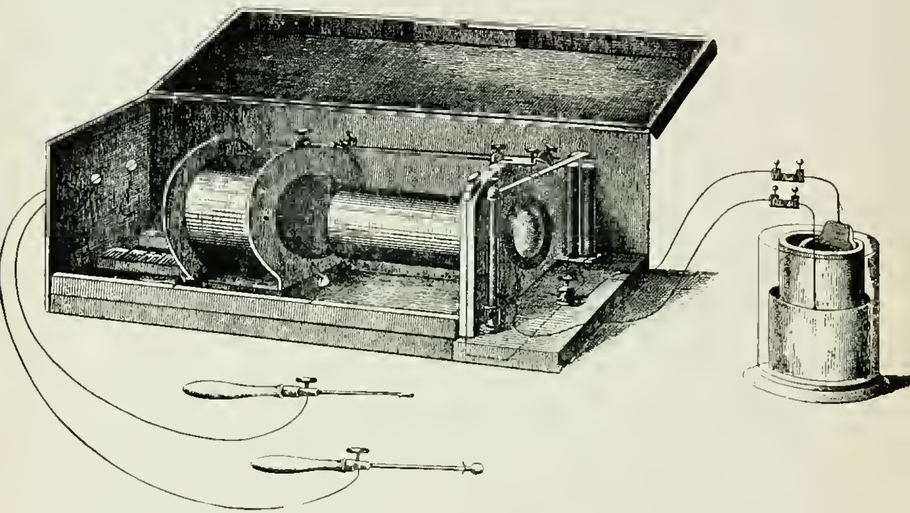
Diagram of Remak's apparatus.

was a careful study of the therapeutic value of the direct, as distinct from the induced current, especially in joint affections, such as rheumatism and gout. According to Althaus, he seems to have had an unfortunate manner of presenting his work to the medical public, so that at first it did not meet with the attention it merited. Owing to the efforts of Benedict, Althaus and others, the value of his electrotherapeutic researches was recognised, and many of his statements which had previously given rise to controversy received a belated acquiescence.

Reference has already been made to the work of von

Ziemssen in determining the situation of the motor points on the surface of the body. To him is also due the careful working out of the effects of making and breaking currents at the cathode and anode respectively.

Wilhelm Heinrich Erb (1840), was the originator of the term, "reaction of degeneration," and contributed a volume on electrotherapy to von Ziemssen's *Handbuch der allgemeinen Therapie* (17 vols., 1875-1885; Erb's volume appeared in 1882). This work was translated into English by



Von Ziemssen's apparatus (*Die Electricität in der Medizin*, 1857).

Dr. de Watteville, and was for some time our standard text-book. Incidentally, it may be mentioned here that the use of the milliampère as the unit in electrotherapeutical work was originally suggested by de Watteville.

About the time we are speaking of, electrotherapy did not receive much attention in this country, as Dr. Lewis Jones writes in his *Medical Electricity**:—

"The employment of electricity in medicine has passed through many vicissitudes, being at one time recognised and employed at the hospitals, and again being neglected, and left for the most part in the hands of ignorant persons, who continue to perpetrate the grossest impositions in the name of electricity. As each fresh im-

* "Medical Electricity," 2nd Edition, London, 1895.

portant discovery in electrical science has been reached, men's minds have been turned anew to the subject, and interest in its therapeutic properties has been stimulated. Then after extravagant hopes and promises of cure, there have followed failures and disappointments, which have thrown the employment of this agent into disrepute, to be again after a time revived and brought into popular favour. During the long period of 200 years, in which these alterations have been taking place in the opinions held of the value of electrical treatment, and in the frequency of its employment, scientific men have been steadily pursuing their investigations into its wonderful properties and possibilities. Discovery after discovery has rewarded their patience, and we have now arrived at an age when the practical applications of electricity are making the most rapid strides. Medical thought and experiment are moving in the same direction, and another wave of electrotherapeutics is passing over the profession. During the last ten years, electrical departments have been re-organised at several of our hospitals, and the powers of electricity have been more and more called in to the aid of the physician and surgeon, and a general desire has been evinced, both by members of the profession and the public, for a more thorough knowledge of the benefits to be derived from this agent and of the best means of securing them."

In his preface to the same work, the author states, that of some three hundred and sixty papers published upon Electrotherapy in 1894, barely a dozen came from Great Britain. There is a passage in the extract I have just quoted which is perhaps deserving of a passing consideration in this connection, and that is where reference is made to the fact that "medical thought and experiment are moving in the same direction." It is surely no exaggeration to say that for five and twenty years after the publication of Darwin's "Origin of Species," the trend of medical scientific thought in England was mainly along what we may perhaps term biological lines. It was not until evolution in some form or other was accepted as proven by all educated persons that physical science again came to the fore, when it made such advances that we may now say that the trend of present-day scientific thought is upon mathematico-physical lines. It is a long hark-back to the time when Joseph Priestley suggested that a study of "the mathematicks" might be useful to intending students of electricity!

Moreover, not only were biological problems largely monopolising the attention of the medical world, but one

branch of biology—the new science of bacteriology—from its immense practical importance, offered unrivalled opportunities in an engrossing and fascinating field of research. Medical electricity had but little to offer in comparison with the problems of bacteriology, whether applied to public health or to surgery ; and this, no doubt, militated against its attracting any large number of enthusiastic students. Now the position is rapidly undergoing a change, and one problem, seemingly an essentially biological one, namely immunity, seeks the elucidation of its findings in physics and mathematics.

In a modest little work (not by the way remarkable for an excess of literary merit), published in 1886, the author informs us in his preface that the then existing insufficient knowledge upon the application of electricity to the treatment of disease is due "to the want of all teaching upon the subject in most of the medical schools."

As a matter of fact, electrotherapy seeems to have been a kind of medical poor relation, and thankful to any physician or surgeon who could bestow a thought upon her.

There are some indications of this is an advertisement appended to an edition of John Wesley's *Desideratum*,* published in 1871. The text of this notice runs as follows : "Mr. T. L. Pulvermacher has the pleasure to announce that his persevering endeavours to improve his Medico-Galvanic System of Flexible Voltaic Batteries in the practical form of chain bands, etc., have been crowned with the most complete success, and that he has been honoured with a flattering testimonial (dated 9th March, 1866), signed by the most distinguished medical authorities in London, including the following gentlemen." Then follows a list :—

Sir C. Locock, Bart., Physician to the Queen.
Sir H. Holland, Bart., Physician to the Queen.
Sir W. Ferguson, Bart., F.R.S., Surgeon to the Queen.
Sir E. Sieveking, Bart., Physician to the Prince and Princess of Wales.

Sir Richard Quain, Sir T. R. Martin, Andrew Clark, F.R.C P., Handfield Jones, F.R.C.P., F.R.S., the Secretary of the

* Original edition published 1759.

Académie de Paris, Dr. Pereira, Dr. Golding Bird, Dr. Russell Reynolds, Mr. Nunn (Surgeon to the Middlesex Hospital).

Now, unquestionably, this was a list of very eminent physicians and surgeons; but, we ask, where are the electro-therapists? for the Dr. Golding Bird indicated above could not have been the pioneer in electrotherapy whom we have mentioned before, since he died in 1854. Althaus, however, presumably was in London at the time, since he read his paper on "Electrolysis" before the Royal Medical and Chirurgical Society in 1867. Here is his opinion of the Pulvermacher Chains.* "The chains are portable, handy, and easily put in action; but they have the drawback inherent to all modifications of the original pile, viz., that the current generated by them is liable to great and sudden variations within a short time. Moreover, in consequence of their small surface and high tension, they are not suitable for being applied to the nervous centres. A prolonged use of these chains, which is generally recommended, is not only opposed to all principles of physiology and therapeutics, but also condemned by daily experience, as, when thus employed, they cause sloughs, the cicatrices of which remain throughout life, and may aggravate the disorder for the relief of which they were brought into play."

It must, however, be confessed that Duchenne had a rather higher opinion of Pulvermacher's apparatus, since he refers to it (in 1855) thus: "La châine de Pulvermacher qui, on le voit, est une heureuse modification de la pile de Volta, à été principalement destinée à être appliquée sous forme de topique, et l'excitation électro-cutanée qu'elle produit peut être avantageusement employée pour combattre les douleurs rheumatoïdes ou les nevralgies rebelles." He, however, characteristically enough, designed another apparatus himself, which he greatly preferred to Pulvermacher's.

Among English physicians who bestowed a kindly thought upon medical electricity was Vivian Poore, who published a work on the subject, *Electricity in Medicine and Surgery*,

* "A Treatise on Medical Electricity," by Julius Althaus, M.D., M.R.C.P., London. Third Edition, 1873. A mine of information upon earlier electro-therapy.

in 1876, and in this work he describes the refreshing action of the galvanic current in counteracting muscular fatigue.

Steavenson, the first of the regular modern electrical medical officers at St. Bartholomew's Hospital, installed an electric bath in his department in 1882, and at his death left a mass of manuscript notes, which formed the nucleus of Steavenson and Lewis Jones's work on "Medical Electricity," which was the parent of what is probably the most popular English text-book on the subject at the present time.

W. E. Steavenson.
St. Bartholomew's Hospital, 1882-1890.

Ionic Medication.

Attempts to introduce drugs into the body by means of electricity date back, as we have already seen, well into the eighteenth century. With the discovery of voltaic electricity the possibility of medication by this means was again suggested by Sir Humphry Davy. In 1833, Fabré-Palaprat endeavoured to introduce iodine by fixing a compress soaked in a solution of potassium iodide and covered with a platinum disc on one of his arms, while another compress soaked in a solution of starch and similarly covered was fastened to his other arm. The disc covering the solution of iodide was connected to the

negative, and that covering the starch to the positive pole of a battery. The current was allowed to pass for a time, and Fabré-Palaprat declared that the starch acquired a blue tint, an observation which has not since been repeated. According to Fabré-Palaprat himself, he was suffering from "ecstatic spasms" (whatever they may be) at the time he was carrying out these investigations, so that, as Althaus remarks, he may have been hardly fit for accurate scientific researches.

In 1846, Klenke, and in 1853, Hassenstein, made similar attempts, the former again employing potassium iodide for "struma," and mercury for syphilis. The findings of both these observers, however, failed to obtain corroboration from other workers.

About this time numerous experiments were performed with a view to obtaining anæsthesia by electrical means, some maintaining that the constant, and others the interrupted current, possessed anæsthetic properties when suitably applied. In 1858, Sir Benjamin Ward Richardson endeavoured experimentally to prove that neither form of current has analgesic properties, and that the only effect of the interrupted current was, in such operations as tooth extractions, to produce a counter shock and possibly divert the patient's attention from the dentist's efforts on his behalf. In the same year Richardson started a series of experiments to ascertain if local anæsthesia could be obtained by electrical medication. He records his first experiment thus:—

"On the 31st of October, I placed a sponge dipped in a solution of morphia on the arm of my friend, Mr. Gregson, and covering this with a copper plate connected with the positive pole of a small voltaic battery, and bringing the negative pole, with a moistened sponge, a little lower on the limb, I caused the current to pass, and produced, in the course of a quarter of an hour, a condition which I had never obtained before; for, on removing the poles, I found that the part over which the narcotic had been applied was pale in colour, and, unquestionably, insensible to pain. Pricked with a needle, Mr. Gregson experienced no sensation; and although the experiment was very imperfect, and its effects transitory, it was sufficiently important to encourage further researches in the same direction."

Some subsequent experiments were performed on animals, when tincture of aconite was applied to the shaven skin:—

"On the 1st of February,* Dr. Halford and Mr. Bainbridge being present, the left hind-leg of a dog was shaved. Around the upper part of the limb I wrapped the broad copper band, including a sponge saturated with a solution made as follows: Tincture of aconite ʒiii, alcoholic extract of aconite ℈i, chloroform ʒiii. A third part of this solution was placed upon the layer of sponge. Around the lower part of the limb, below the ankle, I wrapped another plate of copper enclosing a sponge saturated with water. That done, I connected the upper plate with the positive pole of the voltaic battery, and the lower plate with the negative pole, and set the battery in action. Eleven minutes after the establishment of the current the parts included between the poles were so insensible that they could be transfixed at any point without exciting pain; and at twelve minutes Dr. Halford divided the tendo-Achilles by subcutaneous section, with the same result. The insensibility also extended for a short distance beyond the upper plate. The current was now sustained until the end of an hour, when, the upper plate being removed, Dr. Halford proceeded to amputate the limb. The incision was commenced on the inner side of the leg, some little distance, $\frac{3}{4}$ of an inch, below the knee, and was carried across the tibia to the outer margin of the fibula. The limb was then transfixed, and a flap obtained from the posterior half of the limb; a circular sweep was carried to separate the muscles, and the interosseous membrane was divided. Throughout all these steps of the operation, except in the last, the animal gave no wince or indication of pain; but in dividing the interosseous membrane, he drew up the limb; and in sawing through the bone, he gave a scream as of pain or terror. In the after-steps, including the tying of two arteries and insertion of six sutures, there was no indication of pain.

"Within twenty minutes the animal had eaten two plates of meat, and walked about on his three legs with the utmost unconcern. The wound healed well and gave an excellent stump. On the day after this experiment I found that I could produce insensibility with equal ease in the lids and conjunctiva of the eye of a rabbit."

Richardson continued his experiments with varying success until the end of June of the same year (1859), when he published the second and final part of his communication. Some of the concluding passages run as follows:—

"From the consideration of the experiments and observations now supplied, let us pass, in conclusion, to an impartial survey of the results in their collective sense.

"Firstly, then, it may be accepted as a fact, that by the process I have suggested, such degree of local insensibility may be produced as shall enable the surgeon to perform a large number of

* 1859.

operations without pain. I mean this as a general rule, open, as we have seen, to exceptions.

"This admitted, the question arises as to the mode by which the local anæsthesia is produced. My esteemed friend, Mr. Nunneley, of Leeds (in an essay, published in the *Transactions* * of the Provincial Medical Association for 1849), has pointed out, by a variety of experiments, that the mere local application of narcotic substances will produce a certain degree of local anæsthesia. Nothing could be more conclusive than Mr. Nunneley's argument, and I have all along been alive to the fact of simple absorption as an important part of the process now being considered. The effect of the voltaic current, as I have employed it, makes the insensibility to extend more deeply, and renders it, as a general fact, more complete. A striking example of the difference between an application with or without the current is given in the case of the girl with bursa, on whom the experiment was put to the test with the minutest attention to details and comparisons.

"As to the reason why a continuous current of electricity should exert the influence above named, the argument is simple enough. The current itself has no anæsthetic effect. That is certain; but it has the power of quickening the capillary circulation in the structures through which it is transmitted, and the absorption process is therefore more rapid and determinate. That various medicinal substances may be passed into animal bodies locally by the voltaic current was first suggested (as Dr. Althaus has been good enough to inform me) by Sir Humphry Davy; and Fabré-Palaprat and many other experimentalists have endeavoured since Davy's time to prove this by demonstration. Differences of opinion have thus been called forth; but the first and affirmative statements have never been disproved."

Richardson continues his article with a very impartial review of the relative advantages and disadvantages of his method over freezing and general anæsthesia, and is careful to remark that it is the principle of the method he desires to bring to notice and not any particular form of apparatus or narcotic solution. Subsequently, Richardson withdrew from claiming his method as a practical means of producing surgical anæsthesia. It will be noted that the liquid elements of his narcotic solution were chloroform and alcohol, and probably the effects were due to absorption, assisted by the vaso-dilator effects of these drugs and the local stimulative action of the current. It is also seen that Richardson makes no further claim for his suggestions. So far as he was

* Subsequently known as the *British Medical Journal*.

concerned the whole question at issue was as to its practical utility in surgical practice.

In the last decade of the nineteenth century "Electrical Osmosis" found a limited application in the application of cocaine, the positive electrode being covered with a layer of absorbent cotton moistened with a ten per cent. solution of cocaine. It was recommended that the skin should first be well sponged with hot water, and if five milliamperes of current were used, the skin should be anæsthetic in six or seven minutes.

The development and elaboration of the theory of ionic dissociation by Svante Arrhenius, again revived the question of medication by means of the electric current, and modern ionic medication may be said to owe its inception to Leduc of Nantes and its introduction into this country to Lewis Jones.

Leduc first presented his work to the scientific world at the International Congress of Electrobiology, in 1900, but he had been working at the problem of ionic medication for more than ten years. He was a strong advocate of the use of sodium chloride by this means, as an agent for relieving various sclerotic conditions and for fibrous ankylosis of joints. The use of the zinc ion in the treatment of malignant affections of the skin, and of the salicylic ion in the treatment of neuralgia were also strongly advised by him. Other affections for which he recommended the ionic method were cystitis and ozæna. The first great protagonist of Leduc's scheme of treatment in this country was Lewis Jones, who dealt with the matter at length in a lecture which he delivered before the Hunterian Society in 1905.

High Frequency and Diathermy.

Owing chiefly to the relatively common use in recent years of large induction coils for the production of X rays, high-frequency apparatus has also become a more or less familiar object in electrotherapeutic departments.

Although the discovery of electric waves by Hertz only dates back to 1886, observations which have ultimately proved to be fundamental to the subject were made in the first half of

the nineteenth century, by Joseph Henry. In the year 1842 this eminent physicist described the oscillatory character of the discharge from a Leyden Jar, while further observations, amounting to complete demonstration, were made by the Danish worker Feddersen, in 1850. Henry was not only aware of the oscillatory nature of these discharges, but proved experimentally that the effects of such surgings could be propagated over relatively considerable distances. For instance, he recorded that a spark of about an inch in length from the prime conductor of an electrical machine to a wire circuit placed in an upper room, produced inductive effects capable of magnetising needles in a parallel circuit placed in the cellar, although this was thirty feet below the upper floor and separated from it by two floors each fourteen inches thick. The matter, however, did not attract further attention until it was taken up again by Hertz, although Clerk Maxwell had formulated his electro-magnetic theory of light waves in 1865. Maxwell's theory, although it was worked out to the smallest mathematical detail, remained without actual experimental proof until 1888, when Hertz established the existence of electric waves which conformed to all the laws enunciated by Maxwell.

In order to start these waves, Hertz employed an apparatus which he termed an oscillator, and which consisted of two metal spheres, each provided with a short metal rod terminating in a small metal ball, and so arranged that the small balls were separated from each other by a small space, which formed a spark-gap between them when the spheres were connected to the terminals of the secondary of an induction coil. Each spark passing between them sets up a series of electric oscillations, the duration of each being of the order of about one-hundred-millionth of a second. It is these high-frequency oscillations which are now applied for therapeutic purposes.

In 1889, Joubert noticed that a muscle-nerve preparation from a frog was uninfluenced by these extremely rapid oscillations, and in 1890 it was shown by d'Arsonval that they were without effect upon either motor or sensory nerves. To some extent this had been foreshadowed in 1879, by Ward, who, experimenting with the great Spottiswode coil,

found that accidental shocks obtained when the frequency was about 8,000 per second were less disagreeable than those occurring with lower frequencies. Tripier, employing a Bourseul interrupter, found that with a frequency of 300 per second less painful effects were produced than with the ordinary Neef interrupter. D'Arsonval, making special investigations upon these phenomena, found that with a frequency of 1,500 per second a more or less stationary condition was reached as regards sensory response to the shocks; with higher frequencies the effect diminished, while with frequencies of over 200,000 interruptions per second a cessation of both motor and sensory effect was produced.

On their physical side these high-frequency currents were specially investigated by Tesla and Elihu Thomson, while their physiological effects received attention at the hands of d'Arsonval, who used an apparatus which was first suggested to him by the researches of Oliver Lodge.

Diathermy, or the actual production of heat within the tissues themselves, as the result of the passage of an electric current of high frequency, was first suggested by Nikola Tesla, in 1891. In a paper contributed by him to the *Electrical Engineer*, in the December of that year, he pointed out that when the body was traversed by high potential currents of great frequency a sensation of heat was perceived. D'Arsonval in February, 1891, made a communication to the Société de Biologie, in which he stated the possibility of passing a high-frequency current of three ampères through the body with the production of no other sensation than that of heat. In 1899, von Zeyneck made a passing allusion in the *Göttinger Annalen* to the heating effects of these currents, and in 1907 Nagelschmidt proved that they caused a development of heat within the tissues and recommended their application in articular and circulatory diseases. A further demonstration by the same observer, at the Buda-Pesth Congress in 1908, of a specially designed apparatus for producing this heating effect resulted in the introduction of the term diathermy.

Diathermy was introduced into England by Lewis Jones, at St. Bartholomew's Hospital in 1909, and in the following year Nagelschmidt demonstrated its surgical use upon three

Lewis Jones.
(St. Bartholomew's Hospital, 1890-1911.)

cases in the same hospital. The subsequent advances of diathermy in this country are mainly due to the researches of Cumberbatch, the successor of Lewis Jones at St. Bartholomew's, while at the same hospital, Douglas Harmer was the first of our surgeons to realise its value and to employ it in surgery.*

Electric Illumination Methods in Medicine.†

Although perhaps the subject of electrical illumination for medical purposes does not strictly fall under the heading of electrotherapy, yet for the sake of completeness a few words upon this subject may not be out of place.

Endoscopy, or the illumination and visual examination of accessible body cavities dates back to 1805, when the first recorded attempt was made by Bozzini. Little or no interest was taken in the matter until 1853, when Desormeaux obtained definite practical results, and his instrument received important improvements at the hands of Cruise, of Dublin.

Cruise used as his source of illumination a specially constructed lamp burning petroleum, in which a certain proportion of camphor was dissolved. To avoid inconvenience to the observer from the heat of the lamp, it was enclosed in a suitable mahogany box, and the edge of the flame was directed towards the apparatus it was intended to illuminate. The arrangement of the illuminating apparatus is shown in the accompanying figure, where however, for the purpose of showing the details, the observation tube is represented in a vertical position. For practical use this tube is kept as nearly horizontal as possible, as shown in the next illustration. The instrument here shown was primarily devised for urethro-vesical examinations.

The credit of first employing electricity as the means of illumination must be given to Bruck, a dentist of Breslau. Bruck used a platinum wire heated to a white heat for

* See "Diathermy," by E. P. Cumberbatch (Heinemann, 1921). I am indebted to this exhaustive and interesting work for the details of the foregoing sketch of the subject.

† I am indebted to Mr. Hurry Fenwick for kind permission to reproduce the illustrations from his *Electric Illumination of the Bladder* (Churchill). The summary of the earlier work on endoscopy is from the same source. This book contains a full bibliography of the subject.

examining the cavity of the mouth, and suggested the possibility of modifying the method so as to make it suitable for the examination of the rectum and bladder. The general scheme of the apparatus is shown in the sketch, from which it will be seen that it consists essentially of a platinum spiral, placed in an inner tube and surrounded by a water jacket, in which a constant supply of fresh water is maintained from the attached reservoir. It was not found to be practicable for the examination of the bladder and rectum, although

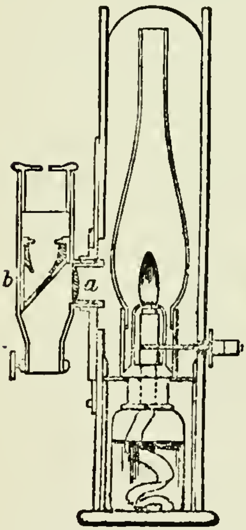
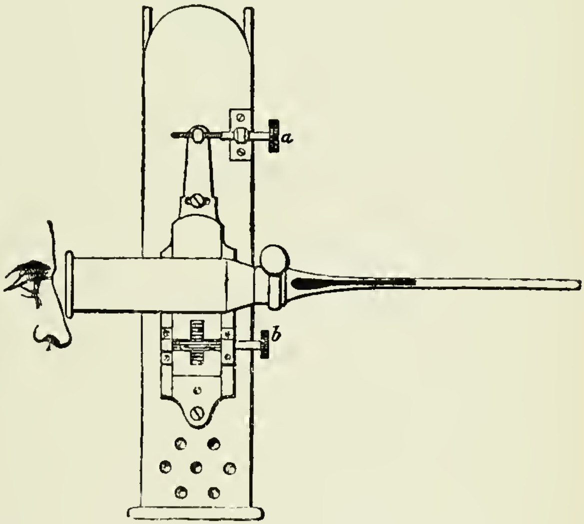


Diagram of proximal end of Cruise's apparatus.



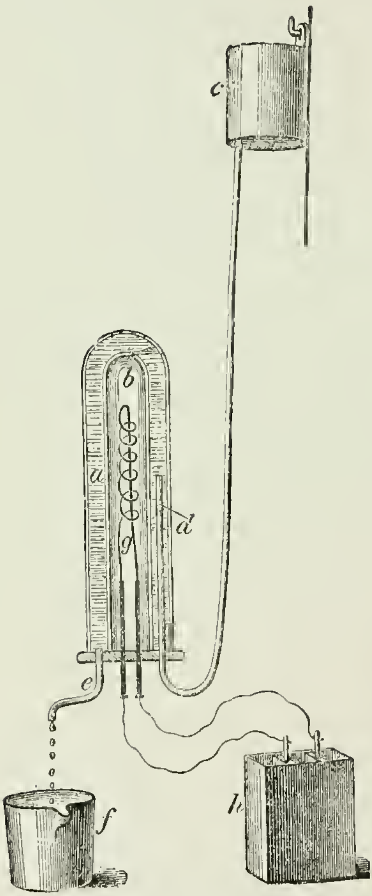
Position of Cruise's apparatus when in use.

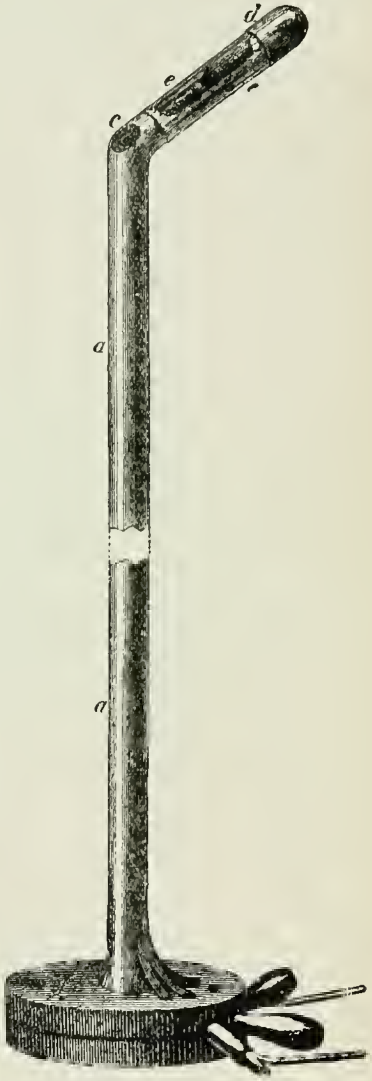
Schramm of Dresden used it when introduced into the vagina, as a means of observing cysts and tumours of the ovaries through the abdominal walls in sufficiently thin patients.

The first electrically illuminated cystoscope was devised by Nitze, in 1876, and in 1877 the idea had been so far developed that a working apparatus for the examination of the urethra bladder and larynx was constructed. Up to this time the apparatus had been made by Deicke of Dresden, but it was next handed over to Leiter of Vienna.

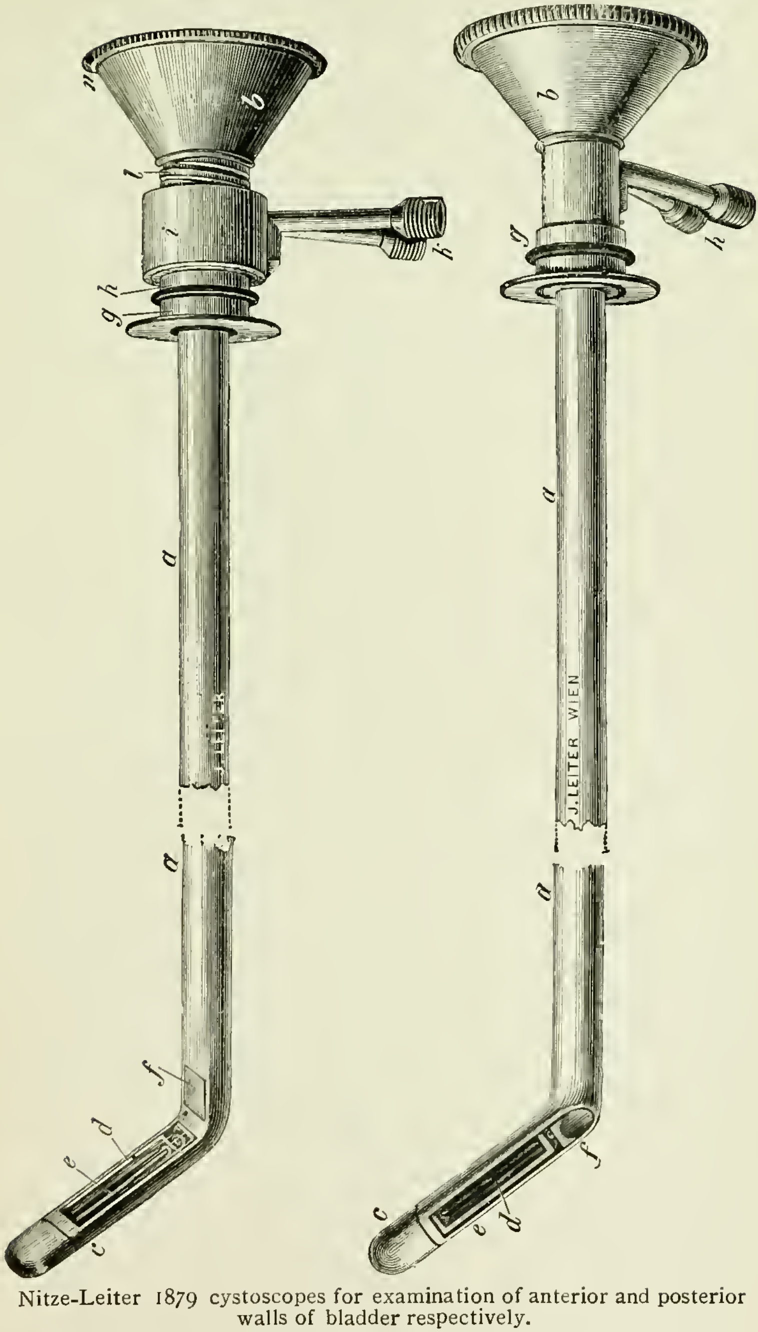
Nitze's cystoscope as handed over to Leiter, is shown in the

next cut. It was a decidedly complicated piece of apparatus, illuminated by an incandescent platinum spiral, and a


Bruck's diaphonoscope.


Nitze's first cystoscope.

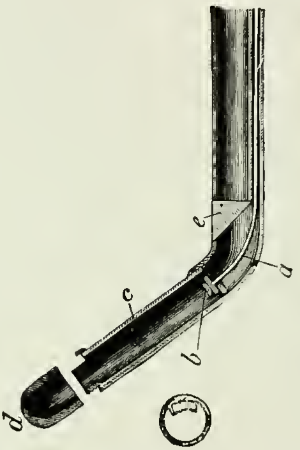
telescope tube had to be pushed home down the stem of the instrument until it reached the opening at *c*. The platinum spiral was protected by a piece of quill, shown at *ee*. This



Nitze-Leiter 1879 cystoscopes for examination of anterior and posterior walls of bladder respectively.

formed one of the most unreliable parts of the instrument, since it was liable to become scorched, and therefore to interfere with the illumination, to say nothing of the possibilities of cracking and consequent leakage. The window *c* in the straight tube was not closed, and consequently the lenses of the telescope tube were apt to be soiled by the contents of the bladder.

Such was the prototype of the instrument subsequently known as the Nitze-Leiter cystoscope, of 1879. Of this, two forms were constructed; one for the examination of the neck,



Beak of Nitze-Leiter 1879 cystoscope in section. Plantinum spiral removed. The small figure shows a tranverse section of the shaft of the instrument.

anterior and lateral aspects of the bladder, and the second for the posterior and basal aspects. The two patterns merely differ in the variations of constructional detail necessary for the attainment of these objects. Once more the source of illumination is the heated platinum spiral, which occupies the whole length of the "beak" of the instrument. The interior of the beak is shown in the next figure, but for the sake of clearness it is represented with the platinum spiral removed. When in position one end of the platinum spiral is received into the hollow metal cup *b*, which is connected with the insulated wire *a*. The other end of the spiral presses against the inner wall of the beak, the body of the instrument thus

serving to complete the circuit when suitable connections are made with the battery.

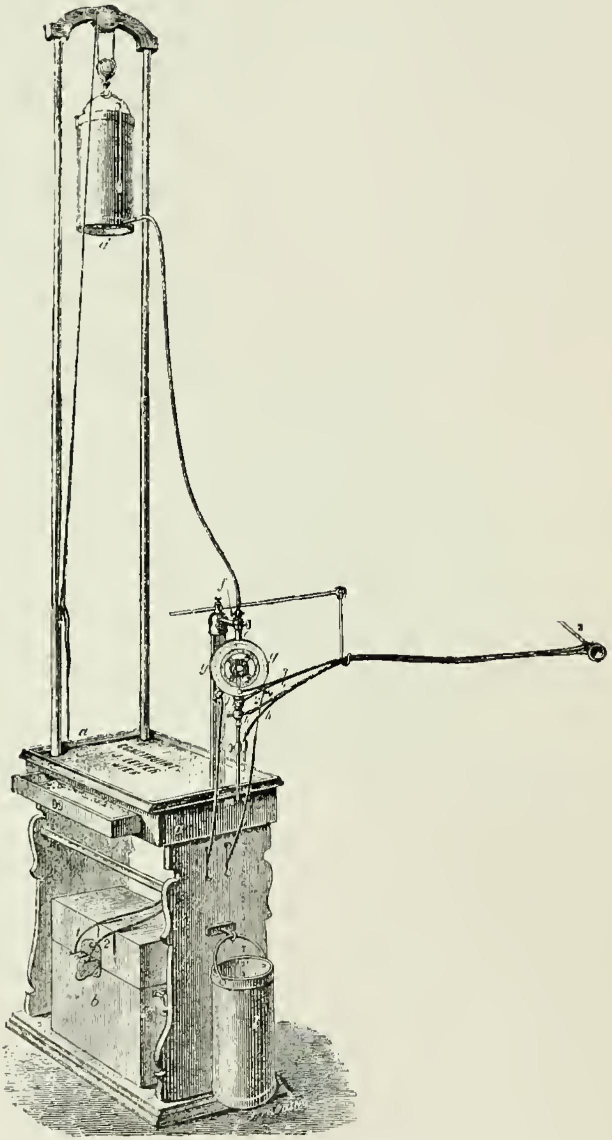
The shaft measures rather over five inches in length, is of number 21 French catheter gauge in size, and on section shows four compartments, as indicated in the next little diagram.

The main tube serves as the telescope tube and is fitted with a suitable system of lenses for magnifying the image transmitted by the window and prism at the lower end. The three smaller compartments consist of two water channels

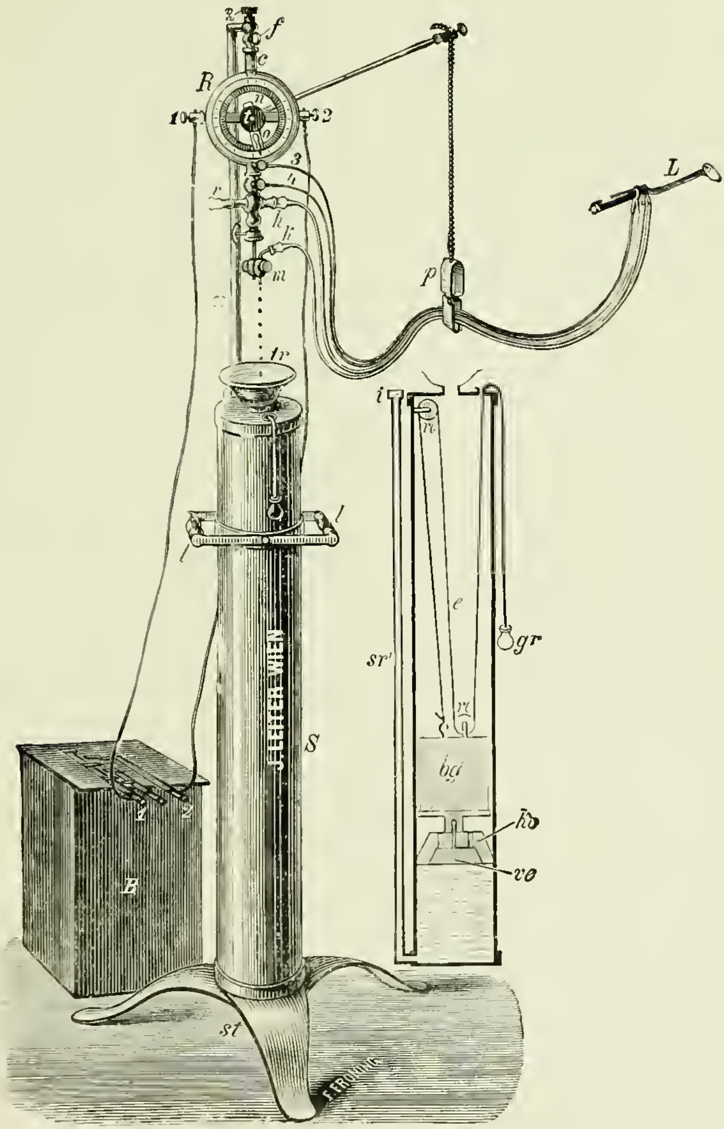
The Nitze-Leiter 1879 cystoscope, packed for transport.

which unite in the beak of the instrument and between them is placed the passage for the insulated wire. The practical difficulties attending the use of such an instrument were, however, very considerable, and not the least of them was that it always seemed to spend a quite undue proportion of time in the workshop of the repairer. Moreover, the water-cooling apparatus was not only complicated but cumbersome, and the entire outfit necessitated the services of a porter for its transport. That this is not a mere *façon de parler* is shown in the annexed sketch, which was introduced into Fenwick's original monograph.

Two forms of water-cooling apparatus were employed, and are shown in the two following figures. The dial-shaped



Water cooling apparatus for 1879 cystoscope (Pattern I).



Water cooling apparatus for 1879 cystoscope (Pattern II).

arrangement, which is seen in both illustrations, is a very important part of the instrument, being in fact a rheostat to regulate the current through the platinum wire. This platinum wire was a constant source of trouble, as any undue increase of current resulted in its fusion and the consequent necessity for repair of the machine. It will be seen that one of the water-cooling systems is worked by means of an elevated reservoir, while in the other a weight forces the water along the necessary channels. The battery used for heating the wire was of the Bunsen type. This apparatus was introduced into this country by Thompson in 1880, while Park was the first to employ it in America.

With the advent of the Edison incandescent filament lamp it was speedily adapted to apparatus for the examination of the throat, nose, ear, and rectum, but it was not until 1887 that it was used in the cystoscope. The designing of the first incandescent lamp cystoscope is due either to Nitze or to Leiter; but the exact priority can perhaps hardly be determined. Nitze had quarrelled with his co-worker Leiter, and his new apparatus was made by Hartwig of Berlin, while Leiter turned out a similar instrument almost simultaneously on his own account. A view of the lower end of the Nitze instrument is shown in the accompanying figure, while Leiter's instruments are indicated in the next diagram.

Fenwick considered Leiter's apparatus as the more practical and useful instrument of the two, and, thus contrasts generally the advantages of the 1887 over the 1879 model :—

(1) The water-cooling apparatus is done away with.

(2) The offensive Bunsen battery and complicated rheostat are replaced by a small plunge battery, which only needs refilling once a month (this was in 1888), or

(3) Accumulators which slip into the pocket may be used.

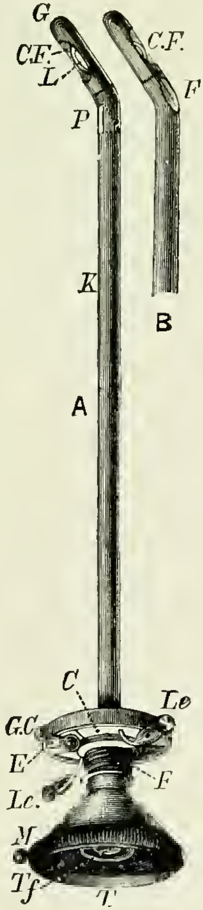
(4) The new instrument is one third the price of the old.

(5) It is neither complicated nor fragile.

Various forms of electrically illuminated apparatus were used in the examination of the larynx and throat, while the gastroscope allowed of a view of the interior of the stomach.

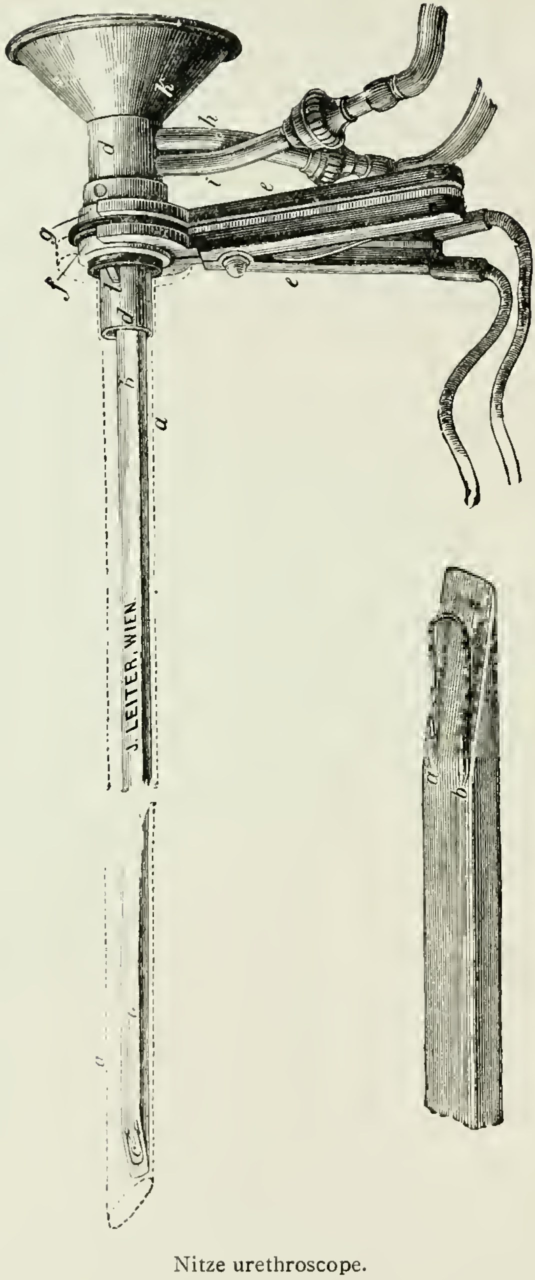
So far as I can ascertain, the pioneer worker in the varied forms of electrically illuminated apparatus for endoscopy was Leiter, of Vienna.

Lower end of Nitze's 1887 incandescent lamp cystoscope.

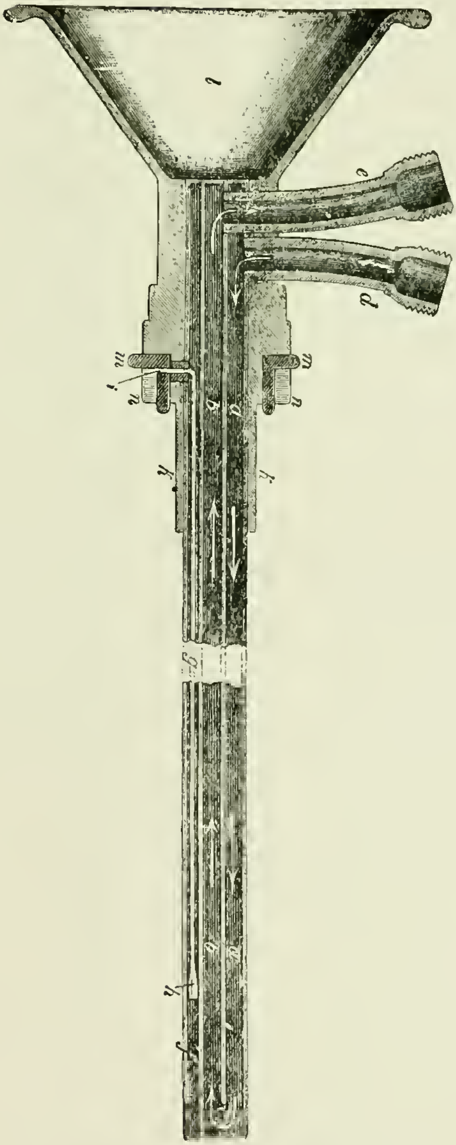


Two forms of Leiter's incandescent lamp cystoscope.

For a long time attempts had been made to obtain good electrical illumination of the fundus of the eye. The ophthalmoscope was first devised by Helmholtz, and numerous attempts have been made to adapt it either for class-demonstration purposes or for photographing the fundus. One of the main difficulties which had to be overcome was the formation

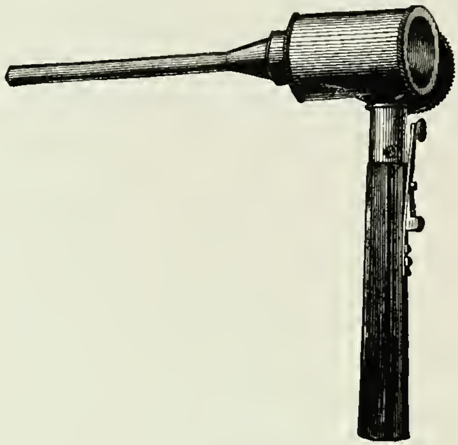


Nitze urethroscope.

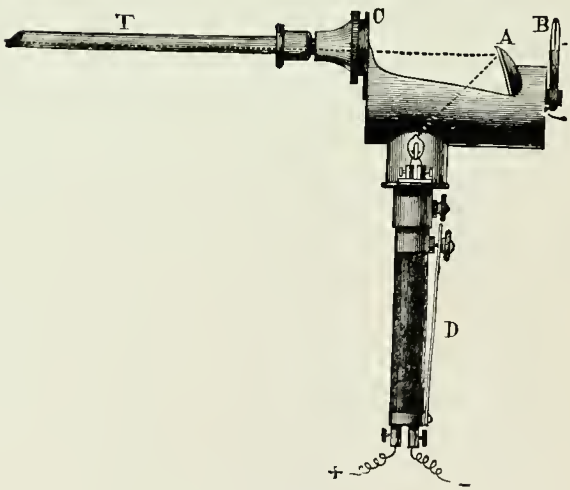


Nitze-Leiter urethroscope in sections.

of reflections at the surface of the cornea and the lens, together with the fact that, in the case of photography, the reddish tint of the fundus of the illuminated eye rendered the



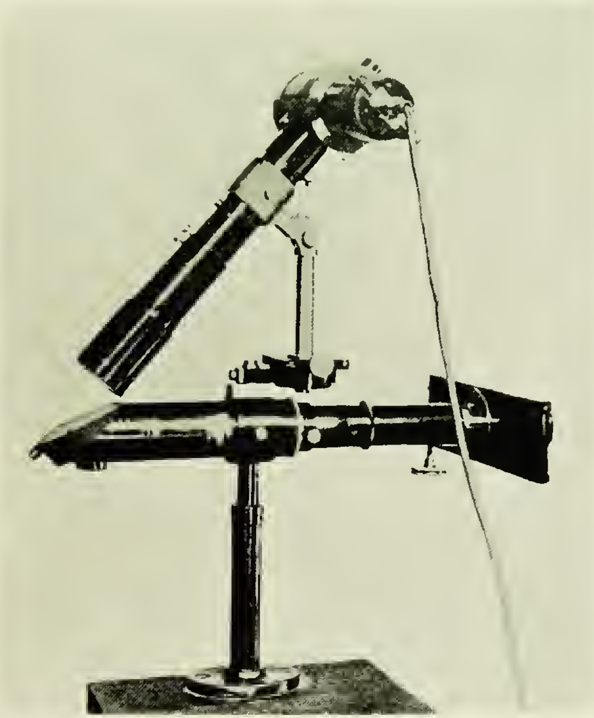
Schall's urethroscope.



Leiter's urethroscope.

process difficult. Among the earlier workers who attacked the problem of the photography of the living fundus, were Bagnéris, Guilloz, Gerloff, and notably Dimmer whose results were usually excellent. A little later, Thorner and

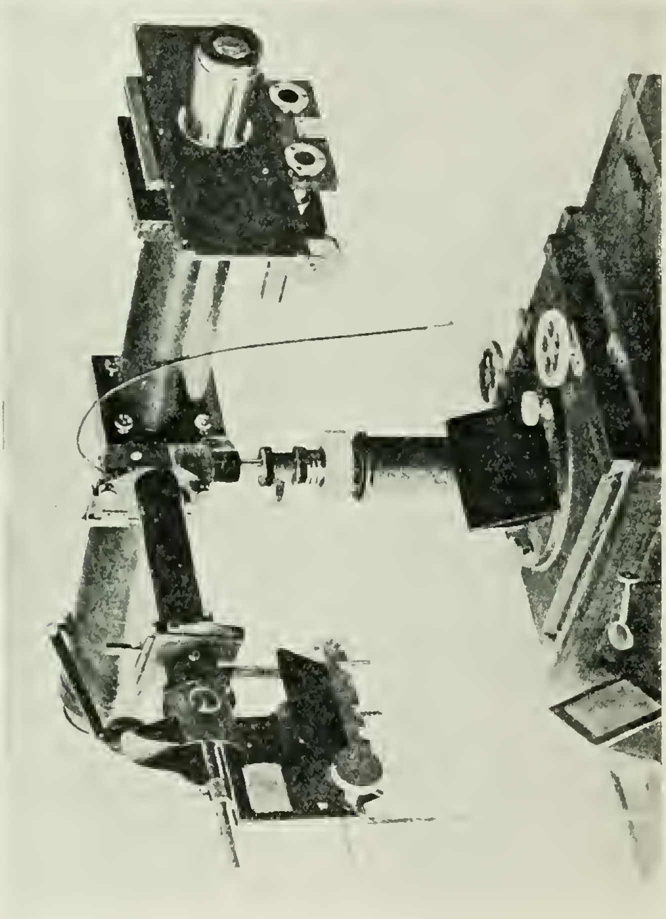
Wolff, though adopting a different method, obtained photographs which were nearly as good as those of Dimmer. The main objection to Dimmer's process is the elaborate and costly apparatus which is necessary, and which, moreover, needs skilled assistance in its use, and also takes up a considerable amount of room.



Professor Wertheim Salomonson's first photographic apparatus.

The various conditions necessary for eliminating the confusing series of reflections were formulated by Gullstrand, and were then embodied in the large demonstration ophthalmoscope of Zeiss, which was, however, unsuitable for photographic work. Owing to the researches of Wertheim Salomonson, of Amsterdam, the various difficulties have been overcome, and beautiful photographs of the fundus oculi in the living subject can now be obtained by his apparatus, a general description of which he published in April, 1917, while a more extended

account appeared in 1919. It would be foreign to our purpose to discuss at length the optical principles involved ; these will be found set forth at length in the second of the two memoirs to which we have just referred. By the kindness

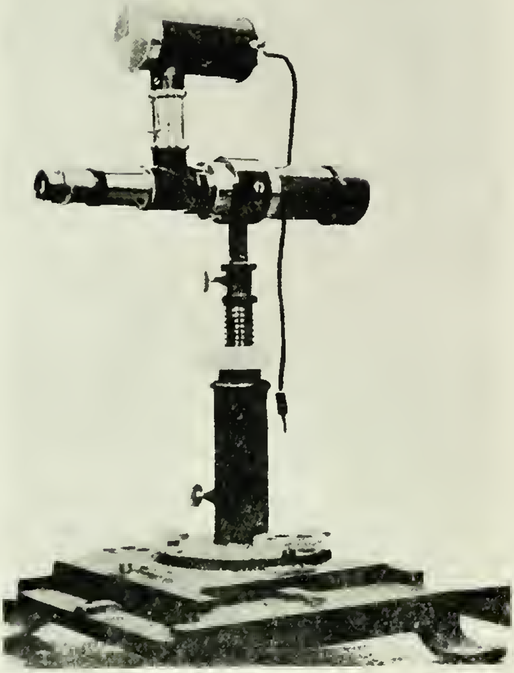


Professor Wertheim Salomonson's second photographic apparatus.

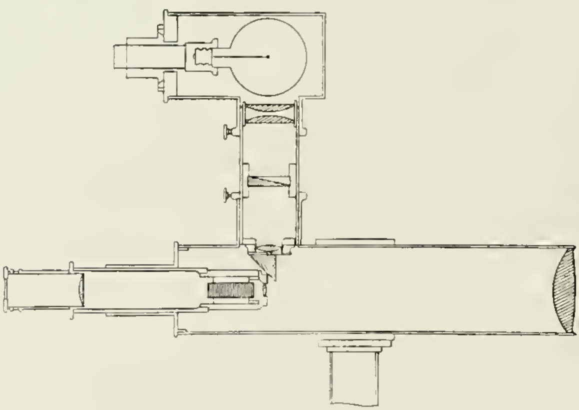
of Professor Wertheim Salomonson, I am enabled to give some illustrations of prints from actual negatives taken by himself. From these it will be seen what an enormous service he has rendered both to ophthalmology and to medicine generally. In December, 1918, the same observer published

Photographs of the fundus oculi, taken by Professor Wertheim Salomonson, of Amsterdam.

1. Normal.
2. Diabetic chorio retinitis.
3. Optic atrophy (*Disseminated Sclerosis*).
4. Choked disc (*Brain tumour*).
5. Showing myelinated fibres.
6. Retinitis, Optic neuritis (*Syphilitic meningitis*).



Professor Wertheim Salomonson's demonstration ophthalmoscope.



Section of Professor Wertheim Salomonson's
demonstration ophthalmoscope.

a description of his new demonstration ophthalmoscope, the construction of which is indicated in the accompanying sectional view.

The Electrocardiograph.

Another application of electricity to diagnostic purposes is seen in the electrocardiograph. This instrument in its present form has been rendered possible by the researches of Waller and of Einthoven. So long ago as 1865 Kölliker and Müller demonstrated variations in the electrical condition of the exposed and active frog's heart ; in the human subject it is manifestly impossible to make direct electrical contact with the living heart muscle. To the English physiologist A. D. Waller, is due the conception that although the heart muscle is not directly accessible in the living human subject, yet the organ is surrounded by masses of conducting tissue, by which variations of the heart's electrical condition may manifest themselves upon the surface of the body. It should therefore be possible, by the application of suitable electrodes to the moistened skin, to register changes in the electrical potential of the heart muscle itself. This was demonstrated to be indeed the case by Waller, and he worked out a scheme of potential differences obtainable upon the surface of the body as the result of the differences obtaining in the heart muscle itself. He figured the body as divided into two parts by an oblique plane ; the part above and to the right assuming the potential of the base of the heart, while that below and to the left assumed that of the heart's apex. This exemplifies the broad fundamental principle of Waller's discovery ; in practice various modifications have been introduced.

At the time of the first publication of Waller's results (1889) the most sensitive instrument available for recording minute differences of potential was the capillary electrometer. This instrument, however, posseses the defect, that it becomes relatively sluggish in response when made extremely sensitive to

(1) *Koninklijke Akademie van Wetenschappen te Amsterdam Proceedings*, vol. XX, No. 2, April, 1917.

(2) *La photographie du fond de l'œil. Archives Néerlandaises de Physiologie l'homme et des animaux. Tome III. 3e livraison*, p. 391. 1919.

minute potential differences. On the other hand, acceleration of response can only be obtained at a sacrifice of sensibility.

These difficulties were overcome by Einthoven of Leyden, who furnished an ideal instrument for the purpose in his "String Galvanometer." This apparatus consists essentially of an exceedingly fine conducting fibre, placed between the poles of a powerful electro-magnet. The fibre which is made of platinum or of silvered quartz, has a diameter of only ·001 to ·003 of a millimetre, and is secured at both ends, so that it is free to vibrate in the same way as a violin string, from which indeed the apparatus derives its name. Now it is known that a wire carrying an electric current, when placed in a magnetic field undergoes deflection in a direction perpendicular to the magnetic lines of force. The direction and extent of the deflection of the conducting fibre will depend upon the magnitude and direction of the current which it conveys when the magnetic field remains constant. Hence, if the terminals connected with the two ends of the galvanometer fibre are brought into contact with the moistened skin of the body by means of suitable electrodes, the fibre will execute movements which for their extent and direction depend on the variations of electrical potential obtaining upon the body surface. For convenience of recording the movements the image of the thread is projected upon a moving photographic film. It is interesting to observe that as late as 1909 Waller himself regarded the apparatus, although of physiological interest, as probably not capable of giving information of any special value when used as an instrument of clinical diagnosis.

The X Rays.

In dealing with the subject of the X rays, I am but too well aware that only the merest outline of their properties and uses can be touched upon. The literature of Radiology has now become enormous, both upon the purely physical and upon the medical sides. At the present time, moreover, with our existing facilities for rapid travel and communication, we meet with a multitude of workers in any given field, and frequently, workers upon similar or almost identical lines. It is, therefore, perhaps almost impossible to assign priority for the discovery

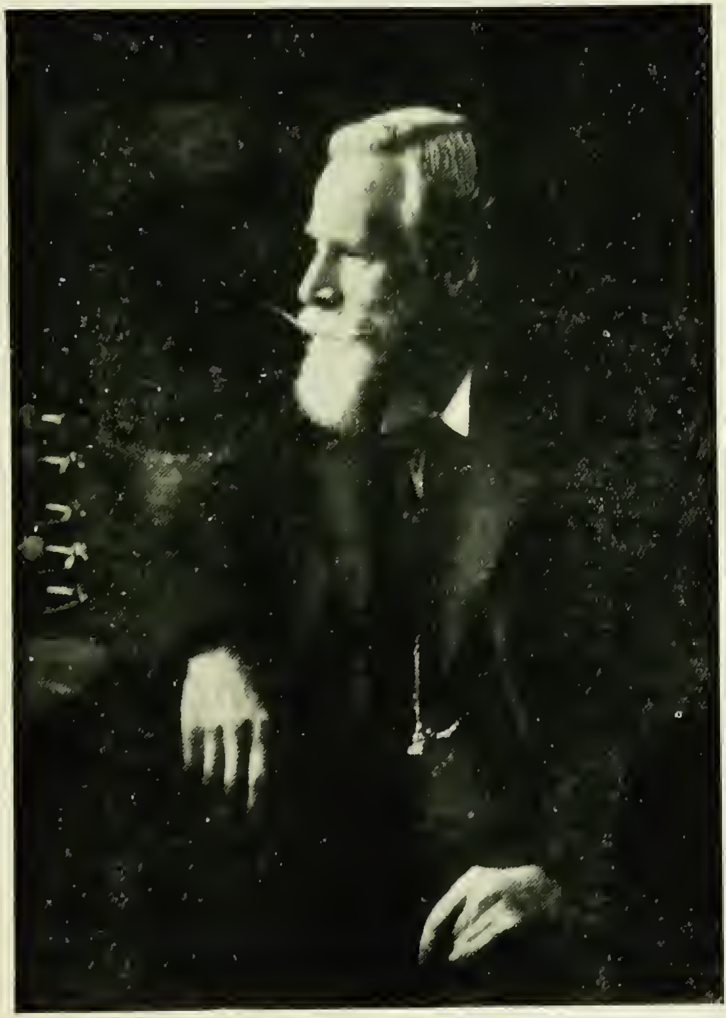
The Electrocardiograph at King's College Hospital.

of each and every development of technique or clinical application. It is, however, my intention to demonstrate, if only in outline, the enormous amount of pioneer work which has been done by British observers in this field of research, work which has but too frequently terminated in the disablement or death of the investigator. This is, perhaps, the more necessary, since in the article on X rays in a standard work of reference the writer can only enumerate three British workers in this sphere of therapeutics, and these three gentlemen are certainly—primarily at least—dermatologists! Nobody would wish to question the excellence of their work or their very high professional standing, but it seems, on the face of it, a little singular, that in a standard work of reference no allusion should be made to any of our radiologists. This omission is, the more flagrant since some dozen foreign workers receiver or rather monopolise, the writer's attention.

The work which rendered possible the discovery of the X rays in 1895, was of course that of Sir William Crookes, upon electrical discharges in high vacua, and which he epitomised in his celebrated lecture before the British Association at Sheffield in August, 1879. Characteristically enough, Crookes began his lecture by acknowledging his indebtedness in many ways to Faraday. The following note by Faraday, in 1819, when he was only twenty-four years of age, is of sufficient interest to warrant our following Crookes' example and repeating it here. Faraday had been dealing with various states of matter, solid, liquid and gaseous, to which he added a fourth, radiant matter. The existence of radiant matter, he admitted, was unproved, but he submitted a series of analogies which he considered rendered such a conception not only possible but probable :—

"I may now notice a curious progression in physical properties accompanying changes of form, and which is perhaps sufficient to induce, in the inventive and sanguine philosopher, a considerable degree of belief in the radiant form with the others in the set of changes I have mentioned.

"As we ascend from the solid to the fluid and gaseous states, physical properties diminish in number and variety, each state losing some of those which belonged to the preceding state. When solids are converted into fluids, all the varieties of hardness and softness are necessarily lost. Crystalline and other shapes are



Sir William Crookes, 1832-1919.

destroyed. Opacity and colour frequently give way to a colourless transparency, and a general mobility of particles is conferred. The immense differences in their weight almost disappear ; the remains of difference in colour that were left, are lost. Transparency becomes universal, and they are all elastic. They now form but one set of substances, and the varieties of density, hardness, opacity, colour, elasticity and form, which render the number of solids and fluids almost infinite, are now supplied by a few slight variations in weight, and some unimportant shades in colour.

"To those, therefore, who admit the radiant form of matter, no difficulty exists in the simplicity of the properties it possesses, but rather an argument in their favour. These forms show you a gradual resignation of properties in the matter we can appreciate, and they would be surprised if that effect were to cease at the gaseous state.

"They point out the greater exertions which Nature makes at each step of the change, and think that, consistently it ought to be greatest in the passage from the gaseous to the radiant form."

About the year 1857 Geissler of Bonn produced what was then termed a vacuum tube. The gaseous contents were reduced to a pressure in the neighbourhood of one hundredth of an atmosphere, and the tubes had wire terminals fused into them, which allowed of their being connected to a Ruhmkorff coil. These tubes, when the current was passed through them, produced beautiful luminous effects, and they can, of course, be procured now as interesting scientific toys. The serious study of electrical discharges in high vacua was undertaken by Crookes, and about 1878 he produced the tube which bears his name, and in which the rarefaction of the residual gas was carried to a degree, measured by a figure of about a millionth of an atmosphere. By means of this tube Crookes was able to demonstrate his cathode rays, and to illustrate many of their properties. For nearly twenty years a controversy raged regarding their nature ; Crookes, Stokes, and the British School generally, holding that they consisted of streams of particles, while the German School held that they were disturbances in the æther akin in nature to ultra-violet rays. The correctness of Crookes' view was incontestably demonstrated in 1897 by J. J. Thomson.

Crookes demonstrated, among others, the following properties of cathode rays :—

1. The faint light which shoots out from the cathode at

right angles to its surface proceeds in straight lines, independently of the position of the anode. In the so-called vacuum tubes, with a relatively low degree of exhaustion the striæ bend round corners and even penetrate into side tubes in order to reach the anode.

2. The rays produce fluorescence upon their impact on solid bodies placed in their path, such as the walls of the tube itself. If a solid body—*e.g.*, a Maltese cross of metal—is set up in the tube it casts a shadow.

3. Objects such as diamonds, rubies, and other minerals, when exposed to the rays in the tube shine with vivid and distinctive colours.

4. They exert mechanical pressure, and can turn light vanes, or drive a suitably arranged wheel along glass rails as in the "Railway Tube."

5. They heat the object struck, and by using a suitable concave cathode they may be made to converge upon a piece of platinum, which may even be fused by the heat.

6. When a magnet is brought near the tube the stream of rays is deflected, and moves across the magnetic field in the same way that a negative current would do.

Before Crookes published his researches Clerk Maxwell in 1873 had written with reference to electrical discharges through rarefied gases :—

"These and many other phenomena of electrical discharge are exceedingly important, and, when they are better understood, they will probably throw great light on the nature of electricity, as well as on the nature of gases and of the medium pervading space."

The prediction had to wait for nearly a quarter of a century for its complete verification, but it is not too much to say that in addition to elucidating some of the obscurities of our electrical knowledge, it has profoundly modified our conception of the nature of matter itself.

In December, 1895, Professor Röntgen* published his discovery of the extraordinary effects of the rays from a Crookes' tube when electrically excited. Probably no other

* A translation of Röntgen's article in the *Sitzungsberichte der Würzburger Physik-med. Gesellschaft* appeared in *Nature*, for January 23rd, 1895.

scientific discovery has ever excited so much widespread and immediate attention. In his Rede Lecture, given at the University of Cambridge, on June 10th, 1896, J. J. Thomson opened his subject as follows :—

"Prof. Röntgen, of Würzburg, at the end of last year published an account of a discovery which has excited an interest unparalleled in the history of physical science. In his paper, read before the Würzburg Physical Society, he announced the existence of an agent which is able to affect a photographic plate placed behind such substances as wood or aluminium, which are opaque to ordinary light. This agent, though able to pass with considerable freedom through light substances, such as wood or flesh, is stopped to a much greater extent by heavy ones, such as the heavy metals and the bones; hence, if the hand, or a wooden box containing metal objects, is placed between the source of the Röntgen rays and a photographic plate, photographs such as those now thrown on the screen are obtained. This discovery, as you see, appeals to one of the most powerful passions of human nature, curiosity, and it is not surprising that it attracted an amount of attention quite disproportionate to that usually given to questions of physical science. Though appearing at a time of great political excitement, the accounts of it occupied the most prominent parts of the newspapers, and within a few weeks of its discovery it received a practical application in the pages of *Punch*."

By the kindness of *Mr. Punch* I am enabled to give a reproduction of this imaginary skiagram, which, like a good many other productions of his versatile genius, has shown itself strangely prophetic. Nevertheless, I am afraid that *Mr. Punch's* success as a prophet is more evident than his skill as a radiographer.

In *Nature*, of January 16th, 1896, the following brief announcement occurs :—

"Prof. W. C. Röntgen, Professor of Physics in Würzburg University, is reported to have discovered that a number of substances which are opaque to visible rays of light are transparent to certain waves capable of affecting a photographic plate. It is alleged that he has been able to utilise his discovery to photograph metals enclosed in wooden or woollen coverings, and has succeeded in obtaining pictures showing only the bones of living persons, the explanation being that, while wood and flesh freely allow the newly discovered actinic rays to pass through them, bones and metals are opaque to them. So far as we can gather from the reports, Prof. Röntgen uses as his source of light one of Mr. Crookes' high-vacuum tubes, electrically excited. If this is placed

on one side of a box containing a metallic body, or if a hand is held in front of it, and a sensitive plate is arranged on the opposite side, a photograph of the metal, or of the bones of the hand, as the case may be, is obtained. The scientific world will look forward with interest to the publication of the details of Prof. Röntgen's work."

As may be imagined, the scientific world did forthwith take a remarkable interest in the new phenomenon. In this volume

THE NEW PHOTOGRAPHIC DISCOVERY.

Thanks to the discovery of Professor Röntgen, the German Emperor will now be able to obtain an exact photograph of a "Backbone" of unsuspected size and strength. —*Punch*, Jan. 25th, 1896.

of *Nature* (vol. 53), which, in all, covers the issues between November 7th, 1895, and April 30th, 1896, the subject of Röntgen rays occupies exactly one column of closely printed matter in the index, although the preliminary notice we have quoted did not appear until the middle of January. The next number of the same journal brought a letter from Professor Schuster, which is interesting as foreshadowing at that early

date our modern views upon the nature of the X rays; he writes as follows:—

"Prof. RÖNTGEN's remarkable discovery will materially affect our views concerning the relation between the ether and matter; but further experimental evidence is required before any opinion can be expressed as to the character of the rays which behave in so straightforward a manner that they seem to upset all one's notions of the laws of nature. Prof. Röntgen, on the strength of his carefully conducted experiments, has arrived at a conclusion adverse to the idea that the rays only differ from light rays by the smallness of wave-length. Perhaps the following considerations may show that the evidence is not conclusive in this respect.

"Röntgen rays are not cathode rays—there can be no doubt on that point—but they are generated at the point of impact between the cathode ray and solid substances. The discoverer has not been able to obtain any interference effects, possibly, as he says, owing to the weakness of the radiation. An absence of interference would not, however, be sufficient to show that the radiation is not of the nature of ordinary light, but only that it does not possess sufficient regularity, or, in other words, that the disturbance is not sufficiently homogeneous. That this is the case is not at all improbable, for the radiation is produced by an impact, which in the first instance may be an impulsive motion propagated outwards, and after passing through the screen, would only possess such regularity as is impressed on it by the absorption of the longer waves.

"The great argument against the supposition of waves of very small length lies in the absence of refraction; but is this conclusive?

"When we speak of the size of the atoms, we mean their distance in the solid and liquid state. The properties of the ether may remain unaltered within the greater part of the sphere of action of a molecule. The number of molecules lying within a wave-length of ordinary light is not greater than the number of motes which lie within a sound-wave, but, as far as I know, the velocity of sound is not materially affected by the presence of dust in the air. Hence, there seems nothing impossible in the supposition that light-waves, smaller than those we now know of, may traverse solids with the same velocity as a vacuum. We know that absorption bands greatly affect the refractive index in neighbouring regions; and as probably the whole question of refraction resolves itself into one of resonance effects, the rate of propagation of waves of very small lengths does not seem to me to be pre-judged by our present knowledge. If Röntgen's rays contain waves of very small length, the vibrations in the molecule which correspond to them would be of a different order of magnitude from those so far known. Possibly we have here the vibration of the electron within the molecule, instead of that of the molecule carrying with it that of the electron.

"I should like, further, to express a certain sense of satisfaction that Röntgen's rays are not deflected in a magnetic field. They are thus clearly separated from cathode rays. The idea that cathode rays are due to vibrations has become fashionable; yet the fact that the magnet deflects them just as it would an electrified molecule, has always seemed to me to be conclusive against this view. No one has, so far, given any plausible reason why a ray of *invisible* light should be able to run round in a spiral, while a ray of *visible* light goes straight; and, so far, Röntgen's rays behave as we should expect well-conducted vibrations to do.

"It is not my intention to argue in favour of any particular theory, or against Röntgen's suggestion that we have at last found the formerly missed longitudinal wave. I only desire to put those points forward which at first sight seem to go against the supposition of ordinary light vibrations, and to raise the question whether they constitute an insuperable difficulty."

In this letter it will be seen that Schuster draws attention to the controversy respecting the nature of the cathode rays. The English school upheld Crookes in his view that they consisted of streams of particles, while the German physicists generally maintained that they were akin in nature to those of ultra-violet light. The matter was settled definitely by J. J. Thomson, who, in 1897, established their particulate character and determined the mass of each particle to be one-thousandth of that of a hydrogen atom.

Within a week after the first demonstration of the X rays, Cox, of McGill University, Montreal, succeeded not only in repeating the fundamental experiments, but in actually employing them for diagnostic purposes. Full details had not reached Canada, but Cox was successful with his first attempt, and four days later he demonstrated a bullet in the leg, where it had remained, giving a good deal of trouble, for seven weeks. The following day it was successfully extracted.

The first X-ray "photograph" (as they were then called), which was taken in this country, was one taken by Campbell Swinton of his own hand, on January 16th, 1896, and now preserved in the museum of the Royal Photographic Society. The duration of these earlier exposures was generally lengthy; thus, twenty minutes was the length of time used by Campbell Swinton to obtain his historic negative. In February, 1896, Porter, of University College, London, pointed out that satisfactory skiagrams could be obtained with an exposure of

four minutes, using a coil with a spark-gap of three inches and worked by three small accumulator cells. Porter's observation was immediately followed by a further note from Campbell Swinton, who recorded a satisfactory skiagram of a human foot, showing the bones almost up to the ankle joint, for which he used a ten-inch coil working at about half power and gave an exposure of fifty-five seconds.

At a meeting of the Paris Académie des Sciences, held on January 27th, 1896, MM. Lannelongue, Barthélemy and Oudin, read a communication upon the utility of the X rays in human pathology. They found that in diseases where there is either a deficiency or an overgrowth of bone, the X rays confirm the previous diagnosis. From Paris also came the news that the X rays could discharge an electroscope even when an aluminium screen is interposed ; the observation was communicated to the Académie in February, 1896, by Benoist and Hurmuzescu, while Chabaud published the results of his work upon the transparency of different metals to the rays. This observer, employing the photographic plate method, confirmed the results which were published by Prof. Röntgen in his original memoir, but which were obtained by the use of a fluorescent screen only. He, however, points out that of the series examined, the two metals which were most opaque to the rays were those of the highest atomic weights, platinum and mercury, while the most transparent to the rays was aluminium, with the lowest atomic weight. Benoist and Hurmuzescu indicated how the electroscopic method might be applied to demonstrating the permeability of different substances to the new radiations.

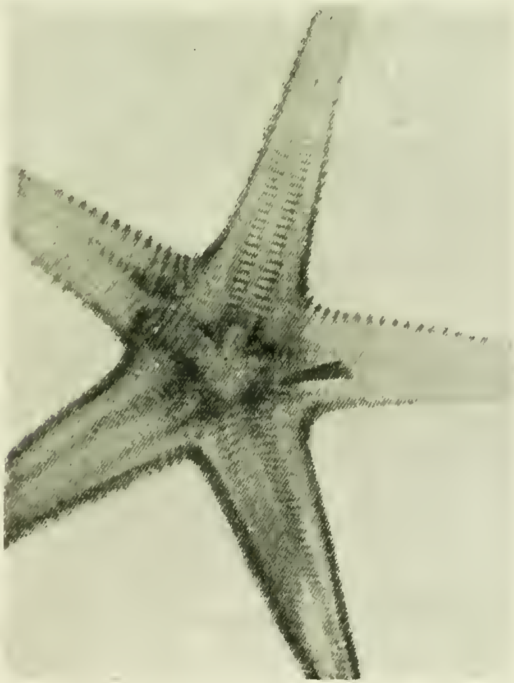
In this country the first skiagram of a gunshot wound was taken by Oliver Lodge, at Liverpool, and recorded in the *British Medical Journal* of February 22nd, and in the same issue appeared the first demonstration of the use of the rays in London for diagnostic purposes, when a fracture of a finger bone was satisfactorily demonstrated at St. Thomas's Hospital.

Towards the end of February, 1896, Campbell Swinton described the results obtained by using a fluorescent screen of barium platino-cyanide mounted in an opaque pasteboard tube.

"The precise arrangement was similar to that recently described

by Prof. Salvioni, of Perugia, whose results, though in accordance with certain experiments of Prof. Röntgen, confirmed, I understand, by Mr. Porter, of University College, have so far been received in this country with a certain amount of scepticism.

"The apparatus consisted of a tube of opaque pasteboard, with a simple aperture at one end, to which the eye was applied. The other end was provided with an opaque diaphragm of double black paper, upon which, on the inner side, was laid a piece of blotting-



Skiagram of *Astropecten*, showing ingested *Dentalium* shell. (Meek, 1896.)

paper impregnated with platino-cyanide of barium in a crystalline state.

"The purse or other object was held against the diaphragm with the Crookes' tube beyond it, so that the rays from the latter cast a shadow of the coins through the leather and black paper upon the inner impregnated screen. The platino-cyanide fluoresced brightly under the stimulus of the rays on those portions of the blotting-paper where no shadow was cast, and consequently the form of the metallic objects was made clearly visible. Non-metallic objects were also seen, though more faintly, owing to their greater transparency to the rays.

"Besides being exceedingly interesting in itself, and possibly capable of sufficient improvement to render it of service in medicine and surgery, the apparatus will be very useful for the purpose of ascertaining, without the tedious process of exposing and developing a plate, whether any given Crookes' tube is suitable as regards exhaustion and form for photographic purposes.

"It can be seen at once whether the tube is working to the best advantage, and is giving clearly defined shadows.

"The place on the glass of the tube from which the maximum radiation is proceeding can also be easily determined, and I may mention, as confirming a point previously noticed by myself—*i.e.*, that a tube with a well marked fatigue spot on the glass will not answer satisfactorily for photography—that with the above described instrument the fatigue spot is visible to the eye through the black paper, thus showing that the glass when fatigued does not transmit the Röntgen rays.

"P.S.—Since writing the above I have been able to see distinctly the bones in the thick portion of my own hand."

The above apparatus is of course only a corollary from Prof. Röntgen's own observations, and the incredulity mentioned probably had reference to some of the absurd reports, which are the inevitable sequel of any great scientific discovery, in the public press. In this case it had been stated that Salvioni had discovered a method of rendering the retina sensitive to the X rays, so that objects were clearly *seen* through planks of wood and other opaque bodies. Judging from remarks which one hears, even at the present day, it would seem that such ideas are not completely extinct in the minds of the general public.

In March, 1896, Edison, in a telegram to Lord Kelvin, reported that he had found crystallised calcium tungstate gave remarkably good fluorescence with X rays, and recommended it for screens in the place of barium platino-cyanide.

About this time, *i.e.*, March, 1896, improvements began to be made in the construction of the Crookes' tube for radiographic work. Hicks, of Firth College, pointed out that a tube with a curved cathode, which converged the streams of rays on a small plane anode, was the most suitable for this purpose. On March 5th, Jackson read a paper before the Chemical Society, in which he described his focus tube,* with

* Jackson's first focus tube for cathode ray experiments was designed in 1894, and thus ante-dated Röntgen's discovery.

a concave aluminum cathode and an inclined platinum anode.

An interesting skiagram of a frog appeared in *Nature*, of March 5th, 1896, in which the effect of a collapsed lung (verified by subsequent dissection) is well shown. The large transparent area, which in the original picture showed a well marked reticulated structure, is the image of the distended

Skiagram of Frog, by Waymouth Reid and Kuenen, 1896. (Taken with small coil 2-inch spark gap and simple cylindrical Crookes' tube.)

lung, while its small collapsed fellow is seen upon the other side. This skiagram was taken by Waymouth Reid and Kuenen.

About the same time Stroud communicated the fact that the time of exposure necessary for obtaining satisfactory skiagrams might be materially shortened by placing a card impregnated with barium platino-cyanide in contact with the photographic plate.

An early attempt at the demonstration of urinary and biliary

calculi was made in March, 1896, and recorded in the *Lancet.* The subject was a dead monkey, into whose kidney a biliary and an uric acid calculus had been inserted. Some indications of a kidney shadow were obtained; the biliary calculus showed hardly any differentiation from the kidney substance, while the uric acid calculus showed quite clearly.

One of the first workers to secure skiagrams showing the soft parts was Macintyre, of Glasgow, who, with the imperfect apparatus which was then at his command, succeeded in demonstrating the heart shadow, as well as the larynx, hyoid bone and tongue. His note on the heart shadow was published in May, 1896. At the Royal Society's Conversazione, also held in the same month, Rowland exhibited a series of skiagrams as applied to medical and surgical diagnosis. Some fifty cases were shown, of which about twenty per cent. had reference to the detection and localisation of foreign bodies, including one of a coin lodged in the intestine. About fifteen per cent. were of more or less obscure lesions of the elbow joint, in which material aid was given to the diagnosis by the X rays, while ten per cent. of the pictures were devoted to the demonstration of the presence and extent of tuberculous lesions of the bones. The remainder of the series consisted of various deformities and ankyloses of the bones and joints of the limbs.

The estimation of the penetrating power of the rays from an X-ray tube was attempted by Reynolds and Branson, of Leeds (May, 1896). The apparatus consisted of a quadrant of aluminium constructed in concentric terraces, ranging from one millimetre to ten millimetres in thickness. It could be used either with a fluorescent screen or with a photographic plate.

The idea of reversing the current in a tube after "fatigue" has set in is due to Barr, and also dates back to May, 1896.

Exhibits of Röntgen-ray apparatus, including a new form of tube for use in the mouth, and stereoscopic skiagrams, were forthcoming at the Royal Society's Conversazione, held in June, 1896. Another important feature in the same section was Macintyre's series of pictures, including not only the skeleton, but the human heart under normal and pathological conditions, while some "instantaneous" plates were also exhibited by the

same observer. The actual time of exposure was unknown, but the most rapid picture was taken with a single flash of the tube, due to one vibration of the interrupter of a ten-inch coil.

At the British Association Meeting, held in Liverpool, in September, 1896, Lister delivered the inaugural address, and in the course of his speech made reference to the X rays in the following terms :—

"I need hardly point out what important aid this must give to the surgeon. As an instance, I may mention a case which occurred in the practice of Mr. Howard Marsh. He was called to see a severe injury of the elbow, in which the swelling was so great as to make it impossible for him by ordinary means of examination to decide whether he had to deal with a fracture or a dislocation. If it were the latter, a cure would be effected by the exercise of violence, which would not only be useless but most injurious if a bone was broken. By the aid of the Röntgen rays a photograph was taken, in which the bone of the upper arm was clearly seen displaced forwards on those of the forearm. The diagnosis being thus established, Mr. Marsh* proceeded to reduce the dislocation; and his success was proved by another photograph, which showed the bones in their relative position."

The account of the case referred to was published by Howard Marsh, in the *British Medical Journal*, May 30th, 1896. Lister was, however, not accurate in his statement that Marsh reduced the dislocation, his share in the transaction was the suggestion that X rays should be used. The X-ray plate was taken by Webster and Moore, while the actual reduction was effected by an Army Surgeon, Captain Salvage.

We must, however, give the priority for a systematic investigation into the diagnostic possibilities of the X rays to the British Medical Association, who commissioned Sydney Rowland to undertake the necessary work. This he did with remarkable thoroughness, and his papers to the *British Medical Journal*, commencing on February 8th, 1896, form an exhaustive report of the possibilities of the rays with the apparatus then at the operator's command. Fractures, dislocations, the detection of foreign bodies, and the examination of various pathological conditions, are all dealt with, and taken together form a monumental piece of work which must always be a classic in the history of radiology. As members of the

* This is a mistake, see next paragraph.

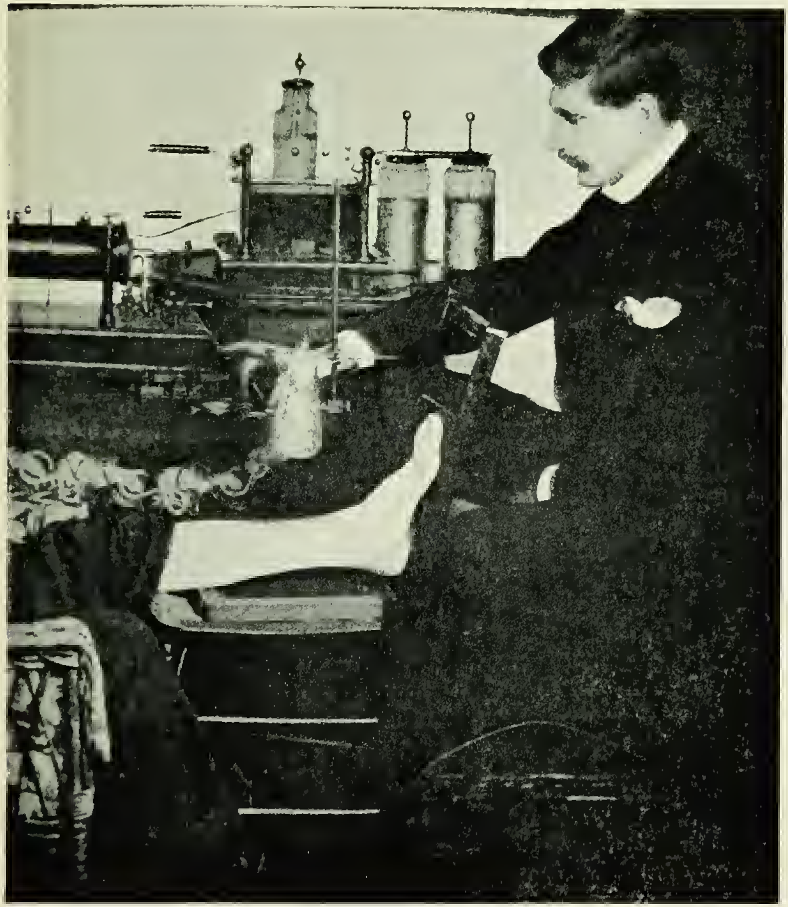
British Medical Association were invited to submit interesting cases for examination, consequently a large number of

Skiagrams of Howard Marsh's case.

names of different observers will be found throughout Rowland's masterly series of articles.

So far we have read of the X rays as agents of deep scientific

interest, of such wonderful properties that they attract public attention to an extent unparalleled in the history of science, and of great and increasing value in diagnosis. Now we have to consider them in a far different aspect. For some time



Early X-ray Apparatus. (Rowland, 1896.)

rumours had been afloat that exposure to the X rays could not be indefinitely continued with impunity; loss of hair was noticed as a consequence of such exposures, and there were more than hints of inflammatory conditions of the skin of greater or less severity. So early as March, 1896, Edison

reported from America that his eyes were sore after experimenting with the rays.

In the *British Medical Journal*, for April 18th, 1896, the following note occurs:—

"Dr. L. G. STEVENS draws attention to the fact that workers on the new method often suffer from a variety of skin affections. In a case under his notice, a gentleman who had been assiduously experimenting with the Röntgen X rays ever since the announcement of their discovery, and who has been working chiefly with the cryptoscope, called attention, when visiting his laboratory, to the condition of his skin. The upper and lower eyelids of both eyes, the alæ nasi and upper lip were all swollen, and the seat of an erythema which was not itchy but very painful. The affection was also present on the hands and wrists, and on the prepuce. On the back of the hands were some raised and hard spots. There was no constitutional disturbance. This and the seat of the eruption point conclusively to irritation as the cause of the eruption. The substances with which he has been working are barium plantino-cyanide, potassium platino-cyanide, and tungstate of calcium.

"These facts have been observed before, but their true interpretation is, perhaps, a little different from the conclusions arrived at by Dr. Stevens. The same phenomena have been observed by other workers, and by workers who have not been using platino-cyanides. From this fact, and from the communication already made to the *British Medical Journal* on snow-blindness, it seems more probable that the observed rash is more of the nature of a sunburn. If this is so, it seems to indicate the presence of X rays as a normal constituent of sunlight, as has already been asserted by continental observers."

In October, 1896, a communication was made to *Nature*, in which the writer gives a vivid description of the effects which exposure to the rays had produced upon his hands:—

"At the request of the Editor of *Nature*, I append the following description, compiled from notes, of the effect of repeated exposure of the hands to the X rays. The result, though perhaps interesting from a medical and scientific point of view, has been most inconvenient and unpleasant to myself—the patient—and although my theories may be incorrect, and my conclusions easy to demolish, there is no mistaking the fact that the X rays are quite capable of inflicting such injury upon the hands as to render them almost useless for a time, and to leave in doubt their ultimate condition when entirely freed from frequent daily exposure to their influence.

"Now for facts. I commenced demonstrating, early in May, with a coil capable of giving an 8-in. spark, and have been engaged in the work for several hours per day until the present time. For the first two or three weeks no inconvenience or discomfort was

felt, but there shortly appeared, on my right-hand fingers, numerous little blisters of a dark colour under the skin. These gradually became very irritating, the skin itself very red and apparently much inflamed. The irritation increased, and the application of *aqua-plumbi*, as recommended in a Berlin telegram to the *Standard*, had only a passing effect in allaying it. So badly did my hand smart, that I was constantly obliged to bathe it in the coldest water I could get, and I really believe I should have been obliged to resign my appointment had not a well known medical man, who happened to attend one of the demonstrations, advised me to use a much-advertised ointment. I did so, with the remarkable result that the irritation left me immediately, and by using it regularly since then I have at least avoided one of the consequences of too much X rays. In the meantime, however, the skin on the fingers had become very dry and hard, yellow like parchment, and quite insensible to touch, and I was not at all surprised to find, a day or two afterwards, that it began to peel off. When this particularly unpleasant operation had been accomplished, I considered I was quite acclimatised to the rays, but soon found out my mistake. The same symptoms again appeared, the newly formed skin going the same way as in the former case. But there was a further discomfort to follow. About the middle of July the tips of my fingers began to swell considerably, and appeared as if they would burst. The tension of the skin was very great, and to crown all, I noticed for the first time that my nails were beginning to be affected. This was the commencement of a long period of really serious discomfort and pain, which was only partly relieved when, from under the nails, there appeared a somewhat copious and unpleasant-smelling colourless discharge, which continued more or less until the old nails were thrown off. With this discharge the swelling in the finger tips decreased, but as the new and old nails began to separate in the middle, the pain was renewed, and I was unable to bear the slightest pressure upon them. The old nails turned quite black and very hard, and the state of my hands may be imagined when I say that I had to keep the fingers in bandages for more than six weeks. It was only in the middle of August that my left hand became affected by the rays, as until then I had principally used my right hand in the manipulation of the fluorescent screen. I naturally expected to undergo the same experience with all its discomforts. I had lost the skin of my right hand for the third time, and there seemed no probability of that being the last. Several doctors had seen my hands and taken much interest in their condition, but no one could suggest a remedy.

"At last it occurred to me that all the trouble was being caused by the rays burning out all the natural oil of the skin, and that if I could in some way supply the deficiency, it might assist in preventing further ill effects. For that purpose I got some lanoline, the oil obtained, so I am informed, from sheep's wool. This I daily

rubbed on my hands and then encased them in a pair of ordinary kid gloves. These gloves, in the course of time, became saturated with the ointment, and there is no doubt that, although in themselves they were quite transparent to the rays, and therefore no shield in themselves, the fatty matter did, in a great degree, prevent the drying up of the skin in the manner I have described. I do not mean to say that it is an absolute preventive, but it goes a long way towards that desirable end, because since I first used the lanoline, now some weeks since, my hands have not again peeled, although at the present moment (October 17th) there are a few slight symptoms of it.

"My view of the effect of the X rays is that in regard to this matter it is exactly similar to acute sunburn. The symptoms and effect are the same, only that in the case of the X rays you have it in a far more concentrated form—in fact, the very essence of it. But whatever may be the cause, the effect is unquestionable. In my case I have had three new sets of skin on the right hand, and one on the left; four of my finger nails have disappeared on the right, two on the left, and three more are on the point of leaving. For at least six weeks I was unable to use my right-hand fingers in any way whatever, and it is only since the nails came off that I have been able to hold a pen. Of course it will be a month or two before my hands resume their normal condition, and it is yet, as I said before, a moot point as to what the end will be.

"I could say much more on this subject, but already I fear I have trespassed too much on the Editor's space. I have written this with the object of placing on record 'the strange case of an X-ray operator,' in the hope that it may add something to what is known of the new and mysterious power, and lead others, more experienced in scientific and medical knowledge than myself, to devise an effectual preventive against such results as I have described. Many important questions are opened up by this remarkable effect of the rays upon the skin and nails, and it may be that in the near future they may be utilised in cases of skin and other diseases. Who knows?'

Both this letter, and the remarks of Stevens, to which we referred previously, demonstrate the totally inadequate view of the enormous potentialities of the rays for evil which the profession then entertained. As was stated in the letter just referred to, it was these lesions caused by the X rays which suggested the possibility of employing them as therapeutic agents. Indeed, already in the January of 1896, Lyon, in a letter to the *Lancet*, raised the question as to whether they possessed any bactericidal properties, indicating that should such prove to be the case, their great penetrative power would open up an enormous field of therapeutic usefulness.

The first employment of X rays as a therapeutic agent seems to be due to Freund, who, in consequence of their depilatory power, used them for the treatment of a hairy mole.

In October, 1896, Downie and Sewell, of Glasgow, noticed vesication of the skin and baldness, consequent upon attempts

Skiagram of tuberculous disease of bones of hand. (1896.)

at the X-ray diagnosis of caries of the cervical spine, and from time to time various lesions, due to exposure to the rays, were reported from this country, from the Continent, and from America. Waymouth Reid, in November, 1896, contracted an attack of X-ray dermatitis, consequent upon his exposing himself to the rays for the purpose of obtaining a demonstra-

tion-skiagram. In January, 1897, more cases were reported from America, including two of considerable severity from Edison's laboratory.

The year 1897 also saw the formation of the Röntgen Society, which held its first meeting at the rooms of the Medical Society, on the 3rd June, under the presidency of Silvanus Thompson, while the Secretary of the Society, David Walsh, published his book on *The X Rays in Medical Work* in the same year. In April, 1897, Gilchrist collected a number of cases of X-ray burns, and published them in the Johns Hopkins Hospital *Bulletin*.

In the following year the X rays were the cause of a lawsuit in France, where the plaintiff claimed damages to the extent of 5,000 francs in consequence of alleged injuries as the result of exposure, while in England three exposures, each of forty-five minutes duration (made to diagnose the condition of a hip after an accident), produced a large sloughing wound which was regarded as responsible for the death of the patient.

Within a year after its formation the *Röntgen Society* appointed a Committee (in May, 1898) to enquire into the possible injurious effects of the Röntgen rays.

By this time some progress had been made in determining in what directions the therapeutical possibilities of the new discovery might lie, and in August 1899, Schiff, of Vienna, read a paper at the British Medical Association Meeting, when he pointed out two classes of skin conditions in which benefit might reasonably be expected. These were :—

1. Those affections in which a depilatory action was indicated.

2. Those cases in which changes in the deeper layers of the skin are called for, such as acne rosacea, lupus, eczema, psoriasis, elephantiasis, and various other conditions.

Investigations continued to be made into the bactericidal action of the rays, especially with regard to tuberculosis, a condition in which it was hoped that their great penetrating power might be of service.

We must now consider some of the points in connection

with X-ray tubes.* The tube used by Crookes in his classical experiments is illustrated in Fig. 1. The extraordinary properties of the rays emitted by such a tube were of course unknown until Röntgen's demonstration of them in 1895; but that this Crookes' tube, made in 1879, could produce X rays was demonstrated by him in 1896, when he produced a skiagram of a grid composed of strips of gold, platinum, silver, copper, and aluminium, and noted the depth of shadow obtained in the case of each metal. Fig. 2 shows the type of tube used by Röntgen in 1895, and Fig. 3 a cylindrical tube in which the glass wall of the tube acts as anticathode, while Fig. 4 illustrates Jackson's focus tube, the first known models of which were designed in 1894. A tube designed by Campbell Swinton, in 1896, for use with alternating currents, is shown in Fig. 5. In this tube each electrode acts as cathode and anode in turn. A tube made by Cossor, in which the cathode rays pass through a ring-shaped anode, is shown in Fig. 6.

It was soon found that with prolonged use the vacuum in the tube became so high as to render the passage of the current extremely difficult, and various devices were suggested for overcoming this difficulty. One of the early forms of regulator is shown in Fig. 7; in this there is a lateral branch containing caustic potash, which, when heated, parts with a certain amount of moisture, and thereby counteracts the tendency to the formation of too high a vacuum. Such a device had been employed by Crookes, and was exhibited by him at the Royal Society, in April, 1879.

A more familiar type of regulator is shown in Fig. 8. A hinged wire is connected at one end with the terminal of the regulator, while the other free end can be brought nearer to, or further from the cathode of the main tube. A spark-gap can thus be set, and if in the course of use the hardness of the tube increases to such an extent that it is more difficult for the current to pass through the tube than across the interval between the free end of the hinged wire and the cathode, the latter path will be taken, and gas will be liberated from the

* A full account of X-ray tubes, by Dr. Rodman, will be found in the *Photographic Journal* for December, 1920. I am indebted to Dr. Rodman for his kind permission to make use of some of the blocks from this article.

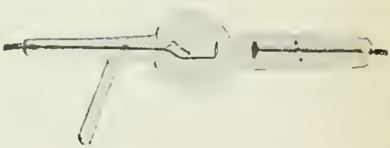
1. Original Crookes' Tube, 1879. 10 inches long.

2. Tube used by Röntgen, 1895. 13 inches long.

3. Early Cylindrical Tube with flat cathode. The wall of the tube acts as anticathode. 12 inches long.

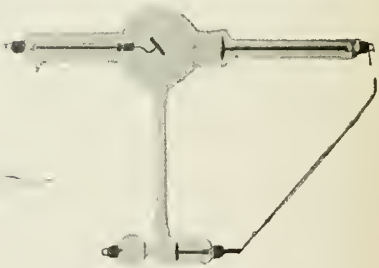
4. Jackson's Focus Tube. 7 inches long.

5. Campbell Swinton's Tube for alternating currents, 1896. 8 inches long.



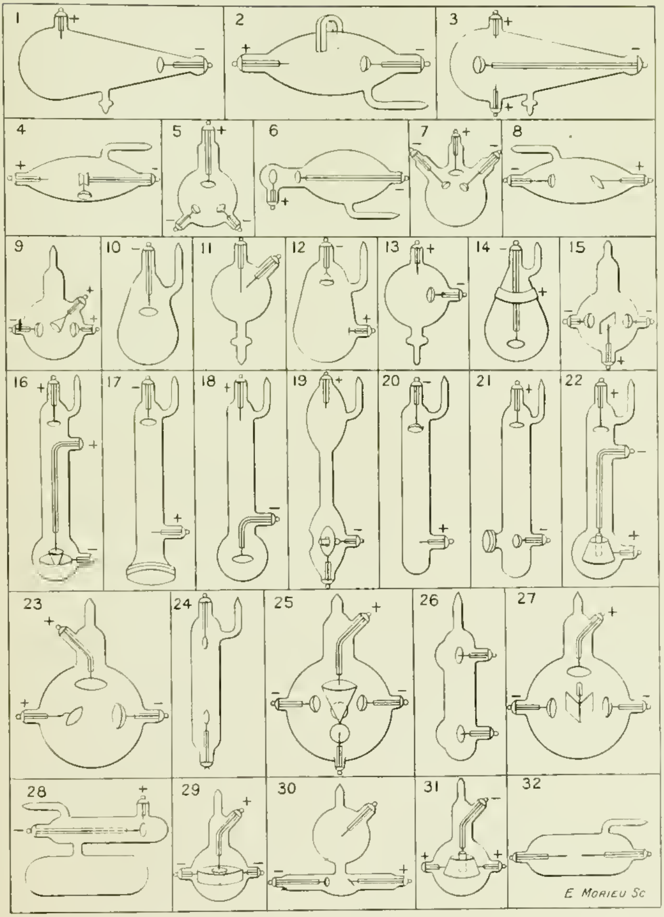
6. "Penetrator" Tube, in which cathode rays pass through ring-shaped anode. Cossor, 1896. 14 inches long.

7. Tube fitted with potash regulator in lateral branch. 8 inches long.



8. Small bulbed Tube with mica regulating device in remote accessory tube. 14 inches long.

Some earlier forms of X-ray Tubes (*Photographic Journal*, 1920.)



Forms of tube used for the production of cathode and X rays.

1, 2. Crookes; 3. Séguy; 4. Wood; 5. Séguy; 6. Chabaud and Hurmuzescu; 7. Séguy; 8. "Focus"; 9. Séguy; 10. d'Arsonval; 11. Séguy; 12. Puluj; 13. Séguy; 14. d'Arsonval; 15. Le Roux; 16, 17, 18. Séguy; 19. Rufz; 20. Crookes; 21, 22, 23. Séguy; 24. Röntgen; 25. Brunet-Séguy; 26, 27. Le Roux; 28. Colardeau; 29. Séguy; 30. Colardeau; 31. Séguy; 32. Röntgen. (*Nature*, January 28th, 1897, after *La Nature*.)

mica which is contained in the regulator. This device is still in use in the ordinary "gas tubes."

A series of early X-ray tubes, shown in the accompanying plate, was reproduced in *Nature* in 1897, from the French journal *La Nature*.

In tubes of later date the anode was in some cases cooled by means of a water jacket, while in other types the same result was obtained by the insertion of a pair of relatively bulky metal "tongs" into a metal tube, which terminated in the anode of the X-ray bulb.

The latest types of X-ray tubes are made upon what is termed the Coolidge pattern, after Dr. Coolidge, who devised the instrument which bears his name in 1913. In this the degree of exhaustion is very much higher, so high in fact that a potential of 100,000 volts applied to the terminals will not pass through the tube. Approximately, the degree of exhaustion of a Coolidge tube is some twenty times that of an ordinary gas tube. The cathode here consists of a tungsten spiral, which can be raised to a very high temperature by means of an electric current, while the electrons or cathode rays are driven off on to a tungsten target by the current applied to the main tube terminals. The device owes its ultimate origin to the researches of Prof. Richardson, of King's College, London, who discovered that cathode rays are emitted by heated metals.

The prototype of the large-sized induction coil was devised by Ruhmkorff, at Paris, in 1851. From time to time various improvements have been added, such as sectional windings, and the development of new forms of interrupter. The ordinary interrupter was found unsuitable for use in X-ray work, and an improved form was designed by Cox. A mercury interrupter was devised by Mackenzie Davidson about 1898, while Wehnelt described his electrolytic apparatus in 1899.

In recent years, transformers have to a considerable extent replaced induction coils for X-ray work. The first practical instrument of this type was constructed by Snook, of Philadelphia, and was introduced into this country in 1907.

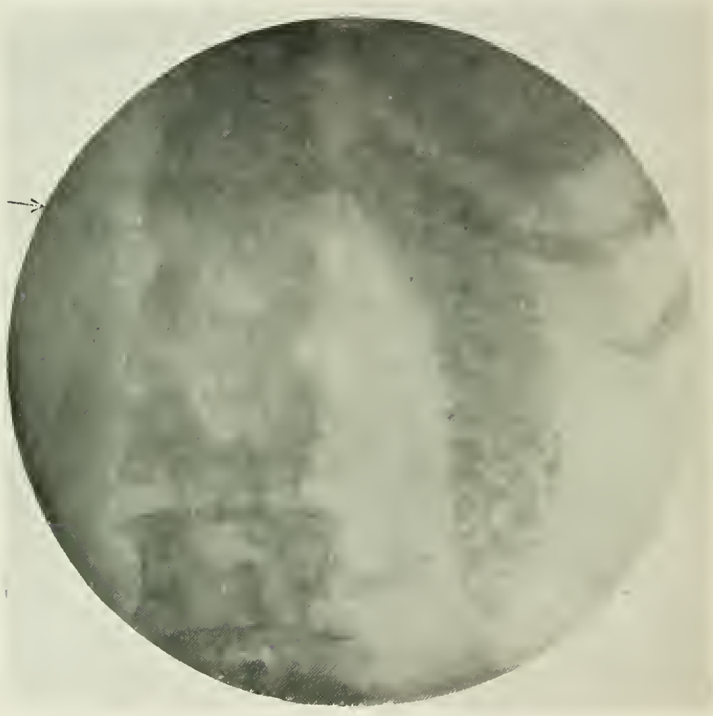
It is almost impossible, in considering a subject of such

rapid development as the practical application of X rays, to give anything approaching a complete list of those who have materially contributed to bring it to its present state, or to avoid the appearance of making invidious distinctions in the selection of names. Considering workers in our own country

H. D. Rühmkorff (1803-1877.)

we may, however, mention: Hall Edwards, of Birmingham, as one of the pioneers upon the essentially practical side; Deane Butcher, of London, as one who was keenly alive to the developments of the subject in other countries, and who did much valuable work in bringing the conclusions of continental observers home to British students, while he was for se era years editor of the *Archives of the Röntgen*

Ray, which had been founded as the *Archives of Clinical Skiagraphy*, by Sidney Rowland, in 1896; John Macintyre, of Glasgow, who in the early part of 1897 gave a practical demonstration of the combined use of the kinematograph and the X rays before the Glasgow Philosophical Society, and who was, moreover, one of the first to obtain successful



Skiagram of Gallstones. (Knox, 1919.)

skiagrams of the soft parts; Mackenzie Davidson and Thurstan Holland, who were among the first to study the important practical question of the exact localisation of foreign bodies; Walsham, Orton and Knox, who have devoted special attention to the skiagraphy of the thorax, while to the last-named observer are also due, not only many details of the special technique requisite for the examination of the gall bladder, including a strong advocacy of the value of the lateral position, but an insistence upon the necessity for adequate protection for

X-ray workers, which is now beginning to receive universal, but belated, recognition; Archibald Reid, who has devoted special attention to the skiagraphy of the renal region, while pyelography, which was devised by Voelcker and Lichtenberg in 1906, and advocated by Braasch, of Rochester (U.S.A.), in 1910, was introduced to English workers by Thomson Walker

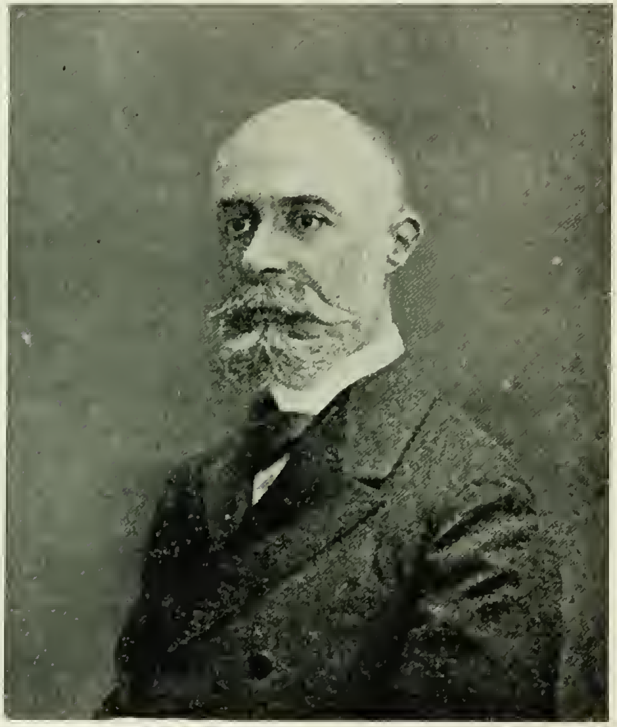
Pyelogram, after Thomson-Walker and Knox.

in 1911, when the skiagraphic side of the question was specially taken up by Ironside Bruce, by Knox, and by Thurstan Holland.

Radium.

On Feburary 24th, 1896, Becquerel communicated to the Académie des Sciences the information that the rays emitted by certain phosphorescent substances could affect a photographic plate through a screen which is opaque to sunlight. The phosphorescent bodies which he used were crystals of

the double sulphate of uranium and potassium, a compound which exhibits fluorescent properties to a very marked degree. The crystals were found to be capable of affecting a photographic plate, not only through a layer of black paper but even through thin sheets of aluminium. These effects were first of all attributed to the fluorescent properties of the uranyl-potassium sulphate, and Becquerel suggested that such



Antoine Henri Becquerel, 1852-1908.

compounds continued to emit radiations which, though imperceptible to the eye, were yet capable of leaving their effects upon the sensitive film of a photographic plate. The duration of the fluorescence capable of affecting the eye which these uranium compounds possess after exposure to light is about one-hundredth of a second, and since the newly described effect could be produced in the dark, it did not seem probable that it could be due to their ordinary

fluorescent properties. On March 9th, the same author made a further communication in which he demonstrated that the radiations from these uranium compounds could also produce the discharge of a gold-leaf electroscope, even although they had passed through an aluminium plate of 2 mm. in thickness. In May of the same year, Becquerel demonstrated that metallic uranium possessed similar properties to those which he had noted in the uranium compounds, and with lapse of time it was noted that these extraordinary effects were independent of any exposure to light.

It was soon afterwards found by Schmidt and Mme. Curie that thorium likewise possessed similar properties. The next step was the examination of different minerals containing uranium and thorium by the electrical method, and noting their power of ionising the air between electrified plates. An astonishing fact was then revealed, namely, that samples of pitchblende from the Austrian mines were four times as active as uranium itself, and other minerals containing uranium showed similar discrepancies. For example, chalcolite, a naturally occurring phosphate of copper and uranium, was twice as active as uranium. If, however, the salt was artificially prepared it presented a degree of activity corresponding merely to the proportion of uranium it contained. The fact thus became evident that there was some other substance present—an "impurity"—to which these naturally occurring minerals owed their extraordinarily active powers. M. and Mme. Curie then undertook their classical investigations in order to track down the substance which was able to produce such extraordinary phenomena. The Austrian government presented these workers with a ton of the uranium residues from the works at Joachimsthal, in Bohemia. These residues had been left after the extraction of uranium from the native mineral pitchblende, and consisted mainly of the sulphates of lead and calcium together with a great variety of other metallic compounds. "To obtain the radium the mixture is heated with concentrated caustic soda solution, the residue washed with water and heated with hydrochloric acid, which dissolves the greater portion of the material. Nearly the whole of the radium is left in the insoluble portion. This, after

washing with water is boiled with a solution of sodium carbonate so as to transform the alkali-earths into carbonates. These are converted into chlorides or bromides, from which by repeated crystallisation barium chloride or bromide is obtained, containing the greater part of the radium as a halide salt. The radium and barium salts are then separated by fractional crystallisation, the former being slightly less soluble in water and alcohol, and in solutions containing the halogen acid, than the latter.

"Pure radium chloride ($RaCl_2$) is a white crystalline salt, resembling barium chloride, with which it appears to be isomorphous. Radium, like barium, forms an insoluble carbonate and sulphate, but a soluble nitrate and bromide. The bromide is much less stable than the chloride; on standing it evolves bromine and becomes basic." *

Thus it is seen that radium occurs associated with the barium constituents of the pitchblende residues. Another radio-active element—polonium—also discovered by Mme. Curie, occurs more particularly along with the bismuth group.

The investigation of the physical properties of radium has, in this country, been more especially the work of Rutherford, Soddy, Thomson, W. H. Bragg and Moseley.

That radium was able to produce effects upon the human skin, similar to the lesions caused by X rays, was first indicated by Walkoff and by Giesel, in 1900. In the *Comptes Rendues*, for 1901, Becquerel and Curie comfirmed the findings of these observers, and Becquerel recorded his own experiences as a result of carrying an insufficiently protected tube of radium bromide. The tube, measuring 15 mm. in length, and with a diameter of 3 mm., was wrapped in paper, placed in a little cardboard box and deposited (for purposes of convenient transport) in Becquerel's waistcoat pocket. It remained there for about six hours, all told. This was on the 3rd of April. On the 10th of the same month an area of redness, measuring 6 by 4 centimetres, had made its appearance; eleven days later the skin disappeared and an ulcerating surface remained, which did not completely cicatrise until the 22nd of May.

The various therapeutic possibilities of its activity were

* Thope, *History of Chemistry*, Vol. II, p. 45.

speedily under investigation, and in February, 1903, Danysz presented a paper to the Paris Académie des Sciences, in which he set forth some of the effects of radium on living tissues, including the skin, the nervous system, and the development of certain insect larvæ.

In 1903, Holzknecht investigated the dermatitis produced by exposure to radium, and recorded beneficial results from its application to cutaneous nodules of melanotic sarcoma, to a carcinoma of the lip and to vascular nævi.

In the September and November of the same year, trial was made of the new agent in cases of malignant disease at the Middlesex Hospital and the Cancer Hospital.

In the January of the following year, Morton, of New York, recorded his experiences of radium in the treatment of cancerous growths. A little later, Exner, of Vienna, reported the results of the treatment of six cases of malignant stricture of the œsophagus. For this purpose 60 mgs. of radium bromide were enclosed in a rubber capsule and introduced into the œsophagus by means of a sound; the duration of the "sitting" in each case was twenty minutes. In the February of the same year Davies demonstrated one of the most useful features of radiumtherapy, namely, its analgesic effects.

In France, a vast amount of work upon the therapeutic possibilities of radium was carried out by Wickham and Degrais, who, in 1909, published an epitome of their results in book form. Wickham and Degrais made use mostly of surface applicators, in which the radium salt was mounted and covered with a thin layer of special varnish; these could be covered with screens of different thicknesses, and in some cases—the "toile" applicators—could be rolled up, enclosed in a suitable screen and introduced into cavities. This method is now less commonly used than formerly. The more usual method, at the present time, especially for the treatment of malignant growths of any size, is the introduction of tubes containing the radium into different parts of the tumour; one or more tubes may be used, and they are arranged so as to produce a cross-fire effect. This technique was suggested by Dominici, of Paris.

Numerous attempts have been made to utilise the active

deposit of radium emanation therapeutically, in many cases with excellent results. The use of radium emanation by inhalation, as carried out in many continental "emanatoria," is still *sub-judice* and requires a considerable amount of disinterested investigation before any opinion can be passed upon it. Certainly many of the claims advanced are strikingly at variance with the experience of the laboratory.

Conclusion.

So far we have endeavoured to trace the history of our subject from antiquity to the present day. In doing so, however, we have necessarily been led to the consideration of the development of different forms of apparatus, somewhat to the exclusion of a connected view of the progress of electrotherapy itself, and of the position which it held in medicine.

In general, I think this will be found to be one of continuous progress, for we must bear in mind that when some of the recommendations of the earlier electrotherapists appear extraordinary or far-fetched, they were suggested as methods of treatment which were either alternatives to pre-antiseptic and pre-anæsthetic surgery, or as experiments upon the treatment of diseases of which the pathology was unknown.

In this connection it is well to remember how essentially modern that system of accurate knowledge which we term "science" really is. For instance, the true significance of respiration dates from the work of Lavoisier, in 1778, while the first attempt to co-ordinate pathological findings with clinical symptoms was made by Morgagni, in 1761. Pathology as a separate subject does not date back earlier than 1793, when Matthew Baillie published his *Morbid Anatomy*. Pharmacology was much in the same situation, and it was, of course, only with the development of chemistry and physiology that it could become in any way scientific. The anodyne effects of opium and the general effects of the administration of some other crude drugs had been known for a considerable time, but such a common drug as digitalis was unknown until 1776, when Withering drew attention to it, while his observation in turn had been directed by an old woman, who said it was

"good for dropsy." The backward state of pharmacology is nowhere better exemplified than in the long survival of theriaca and mithridatum in the Pharmacopœia, whence they were eventually banished by the efforts of Heberden.*

All these matters must be borne in mind, if we desire to investigate the work of the old electrotherapists in a spirit of fair and reasonable enquiry.

Passing over then the ancient and probably prehistoric use of the torpedo-fish and medicinal springs, which latter may have owed some of their efficacy to dissolved radio-active substances, the first attempts to use electricity in medicine were made about 1743, probably by Kratzenstein, of Halle, in the treatment of paralyses. To Jallabert and to Guyot must, however, be given the honour of systematic and scientific application of the new remedial agent by direct stimulation of paralysed muscles, in 1747. This was recognised in the eighteenth century by Mauduyt, who termed Jallabert "Le père de l'électricité médicale." His work, as we have seen, did not receive its due meed of appreciation, owing to the sceptical attitude of Nollet, an attitude which is surely not surprising when we recollect that Nollet had undertaken a journey into Italy expecting to find confirmation of the claims of Pivati and others, but on his arrival discovered that the whole thing was a farce. It will be remembered that Pivati and his co-workers not only claimed an important scientific discovery, but stated that it was capable of employment in medicine as a means of rapidly introducing drugs into the body without oral administration.

Nollet was in many ways an important person. Of humble extraction, he was trained for the Church and took Orders, though most of his energies were directed to the subject of physics. He obtained the post of Maître de Physique to the Dauphin, whence follows the great influence he possessed in making electrotherapy fashionable in France.

To him we owe the term Leyden Jar, and he gives a lively picture of the impression which a shock produced; doubtless

* In this connection it may be remembered—since it is about the only thing known to his credit—that Gideon Harvey so far anticipated Heberden as to point out the absurdity of these preparations as long ago as 1689.

the sensations were not diminished by the fact that they were a little unexpected. Musschenbroeck had stated that the vessel used in the experiment must be of Bohemian or German glass. Nollet, taking the first convenient vessel of ordinary glass, and expecting very little to happen, not only disproved Musschenbroeck's statement, but was not a little startled at the results he obtained:—

"Ce vaisseau, sur lequel je comptais si peu, me servit au delà de mes désirs; dès la première fois je ressentis jusque dans la poitrine et dans les entrailles une commotion qui me fit involontairement plier le corps et ouvrir la bouche, comme il arrive dans les accidents où la respiration est coupée."

In 1747, Louis, surgeon at the Salpêtrière, wrote a pamphlet in which he expressed the opinion that electricity was of no use in medicine. This little work brought forward a rejoinder by Nollet, which illustrates the hopes which he entertained of the good effect of powerful shocks:—

"À peine avons-nous été instruits de la fameuse experience de Leyde que nous avons pensé faire usage sur les paralytiques de cette singulière commotion qui remue et secoue tout un corps jusque dans ses moindres particles; car, quoiqu'on en dise dans un ouvrage qui vient de paraître, et dont le vues sont louables, il était assez naturel de penser qu'une telle secousse pût, en certains cas, ranimer le mouvement dans les membres qui l'avaient perdu."

It seems from this that the endeavours of the influential Nollet were directed to the possible beneficial effects of a thorough shaking-up of all parts of the patient's body, and accordingly the giving of strong and painful shocks came into fashion. He was nothing if not thorough in his experiments. On one occasion 180 of the guards were drawn up in the presence of the king and received a shock; on another a whole community of the Carthusians were drawn up in the convent grounds, in a row 1,800 yards in length, and received a shock which set them all springing off the ground.

This kind of thing seems to have possessed—or perhaps we should say, obsessed—the mind of Nollet to the exclusion of careful attention to the essential details of Jallabert's work. He obtained permission to treat the paralysed inmates of the Hôtel des Invalides; and accordingly, on the 9th of April, 1748, he began to treat three men who had long suffered from

hemiplegia as the result of wounds in the head. The treatments varied. Sometimes the patients were electrified for four or five hours a day, at others, numerous sparks were drawn from them, while shocks from the Leyden Jar were frequently administered. Needless to say, the results were not satisfactory, and as the patients saw no signs of improvement they would not be the subjects of experiment. Nollet's observation at the conclusion of his unsuccessful treatment is emphatic upon the pain inflicted.

"Dès qu'il nous parut, que nous faisions souffrir inutilement (car il faut une grande patience pour se soumettre à cette espèce de torture), nous abandonnâmes tout."

Now, although Nollet had failed, there were certain definite cases of "palsy" which had not only been improved but cured. One such case, reported by Kleyn, of Amsterdam, was that of a woman who was paralysed in both upper extremities as the result of a severe fright. The limbs were wasted and bent, and the fingers flexed upon the palms. This patient made a good recovery after fifteen sittings. As "palsy" was considered a disease and not a symptom, and as electricity could cure some cases, clearly if other cases were obstinate all that was necessary was to give more. And more was given. One case, recorded by Patrick Brydone (who, by the way, was not a medical man), in this country in 1757, was treated by six hundred strong shocks.

Sauvages, of Montpellier, acquired such a reputation through his reputed cures of palsy, that crowds were attracted, and the assistance of the clergy had to be invoked to prove that his results were not due to witchcraft.

If paralysis was an unknown quantity, the same was true of insanity. The effects of powerful shocks were tried upon these unfortunates, and we may assume that, in an age which included flogging and fetters among the routine treatments of the insane, these were not deficient in energy.

Gradually eletrotherapy became less and less in repute, so that it was hardly revived by the discoveries of Galvani and Volta, although the observations of the former, dealing as they did with animal tissues, produced a good deal of purely scientific interest.

In the early years of the nineteenth century, we have the attempts of Aldini and others to resuscitate persons apparently drowned or asphyxiated, while, at the same time, the galvanic current was recommended (as the static discharge had been before) as a safeguard against premature burial; and the discovery of electrolysis led to the unsuccessful attempts of various observers to cure vesical calculus by this means.

The year 1831 witnessed the discovery of electro-magnetic induction, and in 1836 Golding-Bird started his work at Guy's Hospital. In 1847, Duchenne transmitted the account of his work upon localised muscular stimulation through the skin to the Académie des Sciences, a piece of research which revolutionised the whole subject of electrotherapy. The use of the cautery of electrolysis, and the increased application of electricity to diagnostic purposes, belong to the succeeding years. Gradually interest in the subject, in spite of the influence of Althaus and a few others, waned, in this country at any rate, until the eighties of the last century. On a previous page we have ventured to give some reasons for the decline of interest in this branch of medicine, which was doubtless increased to a certain extent by disappointment. The brilliant physiological work of du Bois Reymond, and certain results of Matteucci, which latter were afterwards disproved, had raised exceedingly high hopes, and their non-realisation in practical medicine produced the inevitable reaction.

In 1882, Steavenson was appointed Medical Officer in Charge of the Electrical Department at St. Bartholomew's; other institutions followed suit, and gradually the subject began again to attract attention.

In 1884, Apostoli, of Paris, introduced the scientific use of electricity in gynæcological cases, the advancement of which in Great Britain is largely owing to the work of Sloan, of Glasgow.

The discovery of the X rays by Röntgen, and later of radium by the Curies, have produced an unprecedented interest, and again, in some quarters, have raised hopes which are bound to result in disappointment, unless the wonderful developments of these subjects are carefully and critically examined, and

they are applied therapeutically as the result of scientific research. The great need, at the present time in this country, so far as X rays and radium are concerned, is the establishment of a central institute where such researches can be conducted by qualified workers, where apparatus can be standardised, and adequate means of protection devised to meet the ever-increasing power at our disposal.

THE END.

NOTES.

Note A.—Electric Fishes. (*Page 2.*)

As the Malapterurus figures on the Egyptian monuments, I wrote to Sir E. A. Wallis Budge to ask him if there were any records of the Torpedo. He most kindly answered my queries, but to my disappointment reported that he had not come across mention or illustrations of the fish. The Malapterurus, or cat fish of the Nile, merely appears in groups of other fishes, although the Egyptians can hardly have failed to note its extraordinary powers. It was, however, mentioned by the twelfth century Arab physician, Abd allatif, whose works were translated by Sylvestre de Sacy, and who says : "Nous ne devons pas omettre parmi les animaux propres à l'Egypte le poisson connu sous le nom de Raâda parce que l'on ne peut le toucher quand il est vivant." It is also mentioned in *Purchas His Pilgrimes* (1625), where allusion is made not only to its power of giving sudden shocks, but to its being good to eat.

Stirling (*Journ. Anat. and Physiol.*, XIII, 1879, 350) records a quaint story of a Malapterurus kept in an aquarium with a Clarias. The latter eagerly devoured worms when these were thrown into the aquarium. The Malapterurus, on the contrary, would not touch the fresh worms, but when his companion had well fed he was accustomed to administer a severe shock, so as to make the unfortunate Clarias vomit, whereupon he proceeded to gobble the partially digested worms. It was suggested that this might be one of his usual methods of obtaining food.

Note B.—Magnetism. (*Page 6.*)

The following quotation, from a translation of van Helmont's "Workes," translated by Joseph Constable, of Magdalen Hall, and dated 1664, reads rather like a schoolboy's joke, but it occurs in the body of the text and apparently is meant to be taken in all seriousness. It occurs under the heading *Magnetism*, page 763. "If any shall foul at thy door and thou intendest to prevent that Beastliness for the future ; lay thou a red hot Iron upon the new laid Excrement and by Magnetism, the voyder of that Ordure shall soon go scabby on his Buttocks ; to wit the Fire wasting the Excrement, and as it were by a Dorsal or rebounding Magnetism driving the sharpness of the Roast into his impudent Fundament."

There is a paper which I have not had time to consult, but which may contain some information anent magnetic superstitions

among the ancient Egyptians, *Le Fer et l'aimant en Egypte*, by Devéria, published in *Mélanges d'Archéologie Egyptienne*, Tome I, p. 45.

Note C.—Amber. (*Page* 11.)

The story that Thales was the first to observe that amber, when rubbed, was capable of attracting light bodies, appears like a hardy annual in elementary books of Electricity, and is probably about as true as most other statements of the same kind

Amber ornaments were used by man in the neolithic age, so that it is hardly probable that this property could remain unobserved until the time of Thales. Moreover, Dr. Ladame points out that certain names for amber literally mean "pull straw" (Arabic = Karabé. Persian = Karubà. Egyptian = Sacal. Persian Kah = straw. Raba = to attract). It was extensively used by the ancients, both as an amulet and a medicine, and was included in the first London *Pharmacopœia* (1618); it retained its place in the Pharmacopœias of London, Edinburgh and Dublin until after 1815.

The following extracts from two old works may be of interest :—

"It is dissolvable in Spirit of Wine as also in Oil of Spike, Oil of Lavender and Linseed Oil, tho' with more Difficulty. Amber is reckoned excellent in a cold Intemperies of the Brain, and to be a Specific in Catarrhs. It is prevalent also in Pains of the Head, sleepy and convulsive Diseases, in Suppression of the Menses, in the hysteric and hypochondriac Passions, in a Gonorrhœa, in the Whites, and in Hæmorrhages. The *Dose* is from a Scruple to a Dram in a poached Egg, or any other proper Vehicle. It is to be reduced into an impalpable Powder by Levigation."—*General Dispensatory*, by R. Brookes, M.D., London, 1753.

"It is of no great use in medicine *per se*; as its texture seems too compact to open and yield to the natural elaborations of the body; though some have a great idea of it as a balsamic, and give it in gonorrhœas particularly: and it is also an ingredient in the Gascoign's powder. But certain it is, that what the art of Pharmacy extorts from it is of wonderful efficacy, especially in nervous cases. The salt of amber is an incomparable medicine, as we shall further see hereafter: and the oil likewise is very powerful in many cases, outwardly used. The *Caput Mortuum*, which remains after the salt and oil are gone over, is by some ingenious persons, who have been very inquisitive into this matter, conjectured to afford that powder, which has been so industriously quacked upon the world for a specific in convulsions; and is sold under the title of Dr. Morton's Anti-spasmodic Powder."—*Complete English Dispensatory*, by John Quincy, M.D., London. 1782.

The preparations of amber which were employed in pharmacy were the Spirit, Salt and Oil, and a fourth named *Potestates Succini*, which last, according to Quincy, was but very rarely used.

NOTE D.—JALLABERT. (*Page* 19.)

I was anxious to find a picture of Jallabert, and wrote to my friend, Mr. Hewitt, the Librarian of the League of Red Cross Societies, at Geneva. Thanks to the efforts of Mr. Hewitt and Dr. Charles G. Cumston, I am pretty well satisfied now that there is no portrait of the celebrated Swiss savant in existence. Owing to the interest of Dr. Cumston, numerous enquiries were made about Jallabert in Geneva, and the following extract from a letter addressed by Dr. Hector Maillart to Dr. Cumston will doubtless be of great interest:—

. . . Sa biographie a été faite dans de livre de Ch. Borgeaud : "L'Académie de Calvin" (Genève: Georg & Cie, 1900), pages 568-9. Dans la liste des professeurs qui se trouve à la fin de cet ouvrage, Jallabert est dit né en 1712 alors que Galiffe (Notices généalogiques sur les familles genevoises, Tome III, page 273, Genève, 1836) le fait naître en 1713.

C'est dans Léon Gautier : "La médecine à Genève" qui j'ai trouvé l'idée de Jallabert d'appliquer l'electricité à la médecine. A la page 362, il est dit que c'est sous l'inspiration du professeur de physique Jallabert que le médecin Daniel Guyot (1704-1780) employa le premier l'electricité comme moyen de thérapeutique dans un cas de paralysie. Ce fait a déjà été relaté par Duval dans les Archives des sciences de Mai, 1856, et par Paul Ladame dans la Revue médicale de la Suisse romande, 1885, pp. 553, 625 et 697 ; ce sont surtout les pages 627 à 656 qui parlent des expériences de Jallabert ; mais le mémoire est une très bonne étude sur les débuts de l'électrothérapie.

Qui était Jallabert ? Comme tu le verras par le tableau généalogique que j'ai dressé, c'était un membre de cette aristocratie genevoise qui a tant fait pour l'Etat et pour les sciences. Petit-fils du grand théologien libéral Louis Tronchin, fils d'un pasteur et professeur de l'Académie, sa sœur épouse un Trembley tandis que lui prend pour femme la fille du premier syndic Calandrini ; la sœur de sa femme devient anglaise en épousant un membre de la Chambre des Communes, ministre plénipotentiaire d'Angleterre à la cour de France, Richard Neville-Aldworth ; son fils, épouse sa cousine germaine Neville, mais n'a pas eu d'enfants, de sorte que le nom s'est éteint ; sa fille devient la femme d'un Plantamour, et a eu une nombreuse descendance.

Y a-t-il un portrait du professeur Jallabert ? Il n'en a jamais été reproduit un par la gravure, à ce que je sache quoiqu'on connaisse des portraits gravés par son fils. S'il en existe un original, il est probable qu'il se trouve ou chez un descendant de sa fille ou chez un descendant de Lord Braybrooke, frère de sa belle-fille morte sans enfants. . . .

Il y a aussi une biographie de Jallabert aire bibliographie complète dans : Albert de Montet : " Dictionnaire de Genevois et

des Vaudois," Tome II, pages 4 à 6, Lausanne, Georges Bridel, 1878.

NOTE E.—BECQUEREL. (*Page* 68.)

No less than three members of past generations of the Becquerel family have been illustrious in the world of physics.

ANTOINE CÉSAR BECQUEREL (1788-1878), whose long life lasted from before the French Revolution until a time well within the memory of many persons now living, was one of the distinguished pioneers of scientific physics. During the Napoleonic wars he was an officer of engineers, and was subsequently a co-worker with Ampère. He was the author of a *Traité de l'Electricité et du Magnétisme* (1834-1840) and of other physical works. His son was—

ALEXANDRE EDMOND BECQUEREL (1820-1891), a collaborator with his father, and also a distinguished physicist; is best known for his researches upon the theory of light.

ANTOINE HENRI BECQUEREL (1852-1908), the son of the preceding, was the discoverer of Radio-activity.

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